Industrial QUALITY CONTROL

VOL. V | MARCH, 1949 | NO. 5

Third Annual Convention, ASQC

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Luncheon Meeting — *Principal Speaker* — A. B. Holmstrom, *Vice Pres., Norton Co., Worcester, Mass.*				
THURS. PM	2	2	2	2
THURS. PM	3	3	3	3
Convention Banquet — *Principal Speaker* — Edward Gluck, *Lt. Col., Ordnance Dept., Deputy District Chief, New York Ordnance District*				
FRI. AM	4	4	4	4
FRI. AM	5	5	5	5
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See Pages 16-17 for program details

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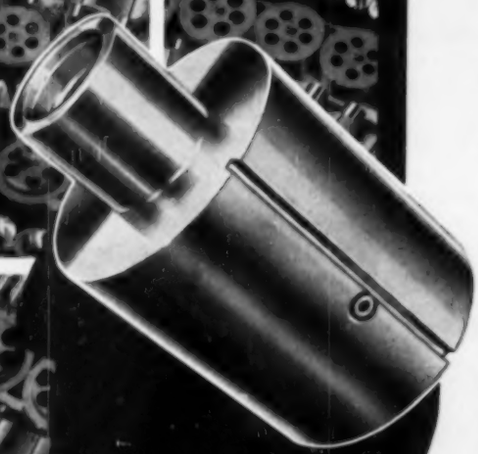

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Instruction will be provided in basic control charts and sampling methods but will also include many of the advance techniques, including design of experiments, correlation, and analysis of variance. Persons enrolling for this course should have a good working knowledge of algebra; advance work in mathematics and previous training in statistics are helpful but not necessary.

The tuition of $100.00 per person includes books and supplies. Room accommodations will be available at, and should be secured by direct contact with, the Hotel Rochester. Further inquiries, and application for enrollment, should be addressed to Alfred L. Davis, Associate Director, Evening and Extension Division, Rochester Institute of Technology, Rochester 8, New York.

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Tuition is $100. For additional information, write to Professor Irving W. Burr, Department of Mathematics, Purdue University, Lafayette, Indiana.

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Quality Control Charts for $\bar{X}$ and R Adjusted for Within-Subgroup Pattern

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INTRODUCTION

In setting up quality control charts for $\bar{X}$ and R, or for $\bar{X}$ and σ[1], it occasionally happens that one is faced with a situation in which it is known or suspected that the values of X in a subgroup are not completely random but tend to follow a "pattern" that is repeated from subgroup to subgroup.[2] If $X_1, X_2, \ldots X_n$ denote the values of X in a subgroup, the situation may be such that the subscripts have an engineering significance. For example, if a chart for weekly averages is being set up to check for assignable causes from week to week, X_1, X_2, etc. may relate to measurements made on Monday, Tuesday, Wednesday, etc. In other examples, the subscripts may refer to the spindles on a machine, the machines in a group, the top, middle and bottom of a steel ingot, etc. If this engineering difference between X_1, X_2, etc. has no or little effect on their values, then the standard quality control charts are applicable. However, in some industrial situations this will not be the case.

For example, in plotting weekly averages based on subgroups of six daily readings in a gas manufacturing plant, the fact that Monday is typically a day of high demand may be reflected in a tendency for readings of some operating variable made on Monday to fluctuate about a different level from those made on other days in the week. Other examples will readily come to the minds of those working on industrial applications. Thus, if one is plotting the average output of several factories (or machines), he may have to recognize the fact that due to certain fixed conditions, the factories (or machines) will differ from each other in their output levels. In other words, an assignable cause **within** subgroups is recognized but cannot be eliminated because of economic or engineering considerations. However, it may still be important to detect assignable causes operating **between** subgroups.

In such a situation the standard procedure for setting up $\bar{X}$ and R charts will result in limits which are too wide on the $\bar{X}$ chart and in limits and points which may be misleading on the R chart. Charts for $\bar{X}$ and R showing such an effect are sometimes encountered in practice.

POSSIBLE PROCEDURES

Several methods might be used for analyzing data suspected of having a subgroup pattern. These include methods based on moving range and analysis of variance techniques. The method currently used in process control appears to be that of substituting 2-sigma for 3-sigma limits. This may be an effective procedure in particular instances but is rather arbitrary.

The method to be described is simple to apply in practice, particularly when dealing with process data, and requires only a limited departure from standard control chart procedures. In this method the values of $\bar{X}$ are computed as usual but the values of R (and consequently the control limits based on $\bar{R}$) are computed from the data after they have been adjusted for possible within-subgroup pattern.

A correction is applied to some of the control chart factors when the number of subgroups is small. It may usually be omitted when twenty or more subgroups are available.

DESCRIPTION OF METHOD

Table I shows some data arranged in twenty-five subgroups, each subgroup consisting of five measurements. The data contain a within-subgroup pattern, since they were obtained by adding —2, —1, 0, +1 and +2 to all values of X_1, X_2, X_3, X_4 and X_5 **respectively,** which were obtained by drawing numbered Bingo chips from a bowl. Control charts for $\bar{X}$ and R are required.

Values of $\bar{X}$ are computed for the subgroups as usual and averaged to give $\bar{\bar{X}}$. In addition, the averages for the X_1, X_2, etc. values are computed and entered to the right of the table. These averages are subtracted from all values of X in the same row to give the adjusted values shown in Table II. Subgroup ranges are computed for these adjusted values and averaged to give an $\bar{R}$.

The central lines and limits are then computed as follows:

Chart For $\bar{X}$

Central line ..... $\bar{\bar{X}}$

Control limits ..... $\bar{\bar{X}} \pm A_2\bar{R}\sqrt{m/(m-1)}$

1.—Only $\bar{X}$ and R will be discussed, the extension to σ will be obvious.

2.—Shewhart's Criterion II provides a test for such a pattern.

Chart For R

Central line . . . . . $\bar{R}$

Control limits: . . . . . $D_3\bar{R}$ and $D_4\bar{R}$

where $\bar{\bar{X}}$ and $\bar{X}$ values are computed from the unadjusted data, $\bar{R}$ and R values are computed from the adjusted data, A_2, D_3 and D_4 are the usual factors from the ASTM Manual on Interpretation of Data, m is the number of subgroups, and values of $\sqrt{m/(m-1)}$ are given in Table III.

The upper part of Figure 1 shows an $\bar{X}$ chart plotted from the data in Table I with two sets of control limits; one computed as described above, the other computed by the standard method. It is evident that the standard limits are much wider. The limits based on the adjusted data are very close to those obtained by analyzing the original data, i. e., before a within-subgroup pattern was added, by either the standard or the proposed method.

There is not complete independence among the values of R computed from adjusted values of X. The m values of R, so obtained, are equivalent to a set of (m-1) independent values of R, which is allowed for by the factor $\sqrt{m/(m-1)}$.

If the new procedure is applied to data in which in fact there is no subgroup pattern, practically the same limits will be obtained as by the standard method. There is a slight loss of efficiency of estimation equivalent to the loss of one subgroup.

The lower part of Figure 1 shows two range charts; one computed as described above, the other computed from the unadjusted data by standard methods. The standard limits are wider and the points show a different arrangement.

An insight into the effect of within-subgroup pattern on the standard R chart can be gained by taking an extreme case in which the pattern practically submerges all other variation. The limits would then be very wide and all points on the R chart practically at the center line.

EXTENSION OF CONTROL CHART LINES

The central lines and control limits can be extended for both the $\bar{X}$ and R chart*. However, the new values of R plotted must be computed from X values adjusted by subtracting the same averages of X_1, X_2, etc. as were used in Table II. In practice, these averages should be recomputed at intervals.

*—This is not exactly equivalent to the procedure of the next section but is simpler and will not differ materially if approximately 20 subgroups are used.

TABLE I. DATA BEFORE ADJUSTMENT

	Subgroup Number																					Row Aver.	Symbol
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)		
X_1	1	−3	−1	−4	0	−2	−4	0	−1	−2	−2	−4	−3	0	1	−3	−4	−2	−2	−1	−4	−1	−2	−3	−2	−1.92	$\bar{X}_1$
X_2	−3	1	−2	−1	−4	−2	0	0	−2	−1	1	−1	−5	2	−2	−2	0	−1	−1	−1	1	−4	−1	1	−3	−1.20	$\bar{X}_2$
X_3	−5	0	−1	−2	1	1	2	1	−2	−2	−2	3	−1	0	0	−2	1	−1	1	1	0	0	−1	0	0	−0.32	$\bar{X}_3$
X_4	1	3	−2	3	0	3	0	0	−1	4	4	−1	2	4	1	−4	2	4	1	0	−2	−2	2	−1	2	+0.92	$\bar{X}_4$
X_5	1	2	2	4	2	3	2	2	3	4	2	0	0	2	−1	2	3	−1	−1	2	1	1	1	3	2	+1.64	$\bar{X}_5$
$\bar{X}$	−1	0.6	−0.8	0	−0.2	0.6	0	0.6	−0.6	0.6	0.6	−0.6	−1.4	1.6	−0.2	−1.8	0.4	−0.2	−0.4	0.2	−0.8	−1.2	−0.2	0	−0.2	−0.176	$\bar{\bar{X}}$

TABLE II. ADJUSTED DATA

	Subgroup Number																									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	
$X_1+1.92$	2.92	−1.08	0.92	−2.08	1.92	−0.08	−2.08	1.92	0.92	−0.08	−0.08	−2.08	−1.08	1.92	2.92	−1.08	−2.08	−0.08	−0.08	0.92	−2.08	0.92	−0.08	−1.08	−0.08	
$X_2+1.20$	−1.8	2.2	−0.8	0.2	−2.8	−0.8	1.2	1.2	−0.8	0.2	2.2	0.2	−3.8	3.2	−0.8	−0.8	1.2	0.2	0.2	0.2	2.2	−2.8	0.2	2.2	−1.8	
$X_3+0.32$	−4.68	0.32	−0.68	−1.68	1.32	1.32	2.32	1.32	−1.68	−1.68	−1.68	3.32	−0.68	0.32	0.32	−1.68	1.32	−0.68	1.32	1.32	−0.32	0.32	−0.68	0.32	0.32	
$X_4-0.92$	0.08	2.08	−2.92	2.08	−0.92	2.08	−0.92	−0.92	−1.92	3.08	3.08	−1.92	1.08	3.08	0.08	−4.92	1.08	3.08	0.08	−0.92	−2.92	−2.92	1.08	−1.92	1.08	
$X_5-1.64$	−0.64	0.36	0.36	2.36	0.36	1.36	0.36	0.36	1.36	2.36	0.36	−1.64	1.64	0.36	−2.64	0.36	1.36	−2.64	−2.64	0.36	−0.64	−0.64	−0.64	1.36	0.36	
$R=$	7.60	3.28	3.84	4.44	4.72	2.88	4.40	2.84	3.28	4.76	4.76	5.40	4.88	2.88	5.56	5.28	3.44	5.72	3.96	2.24	5.12	3.84	1.76	4.12	2.88	

$\bar{R}=4.155$

CONTROL—STANDARD GIVEN

Here, standard values designated $\overline{X}'$, σ' and $\overline{X}'_1$, $\overline{X}'_2$, etc. are given. These are usually obtained from prior data showing control: the $\overline{X}'$ being a long run $\overline{\overline{X}}$; σ' being estimated from $\overline{R}\sqrt{m/(m-1)}/d_2$, where $\overline{R}$ is a long run average range computed from adjusted X values; and $\overline{X}'_1$, $\overline{X}'_2$, etc. are long run averages used in adjusting the X values as shown in Tables I and II.

The central lines and control limits are then computed as follows:

Chart For $\overline{X}$

Central line ..... $\overline{X}'$
Control limits ..... $\overline{X}' \pm A\sigma'$

Chart For R

Central line ..... $d_2\sigma'$
Control limits ..... $D_1\sigma'$ and $D_2\sigma'$

where the $\overline{X}$ values are computed from the unadjusted data, the R values are computed from X values adjusted by subtraction of $\overline{X}'_1$, $\overline{X}'_2$, as shown in Tables I and II, and d_2, D_1 and D_2 are the standard ASTM control chart factors.

EXAMPLE 1

An illustration based on data having an obvious within-subgroup pattern is afforded by Table IV and Figure 2.

In Table IV are given the number of degree-days for each month from September to May inclusive for fifteen heating seasons in Toronto, Canada. The number of degree-days for a month was obtained by subtracting from 65°F. the mean temperature for each day in that month which had a mean temperature less than 65°F., and summing for the month. For each heating season, the average monthly number of degree-days was computed as shown in Table IV, each heating season constituting a subgroup. There is an obvious within-subgroup pattern, the degree-days for January in any season, for example, being higher than the degree-days for September.

The $\overline{X}$ values of Table IV are plotted in Figure 2. If the within-subgroup pattern is ignored in computing control limits, limits of 1150 and 379 are obtained, which are beyond the scale of the figure. However, if the method of this paper is followed, the limits 874 and 656 shown in Figure 2 are obtained.

EXAMPLE 2

In rolling sheet metal strip, thickness measurements were made at intervals along a coil at each edge and at the middle. They were then averaged along the coil to give a thickness value for each edge and for the center, as shown in Table V. These three values for each coil constituted a rational subgroup, but an inspection of the data showed that

TABLE III. VALUES OF $\sqrt{m/(m-1)}$

m	$\sqrt{m/(m-1)}$	m	$\sqrt{m/(m-1)}$	m	$\sqrt{m/(m-1)}$
1		11	1.05	21	1.02
2	1.41	12	1.04	22	1.02
3	1.22	13	1.04	23	1.02
4	1.15	14	1.04	24	1.02
5	1.12	15	1.04	25	1.02
6	1.10	16	1.03	26	1.02
7	1.08	17	1.03	27	1.02
8	1.07	18	1.03	28	1.02
9	1.06	19	1.03	29	1.02
10	1.05	20	1.03	30	1.02

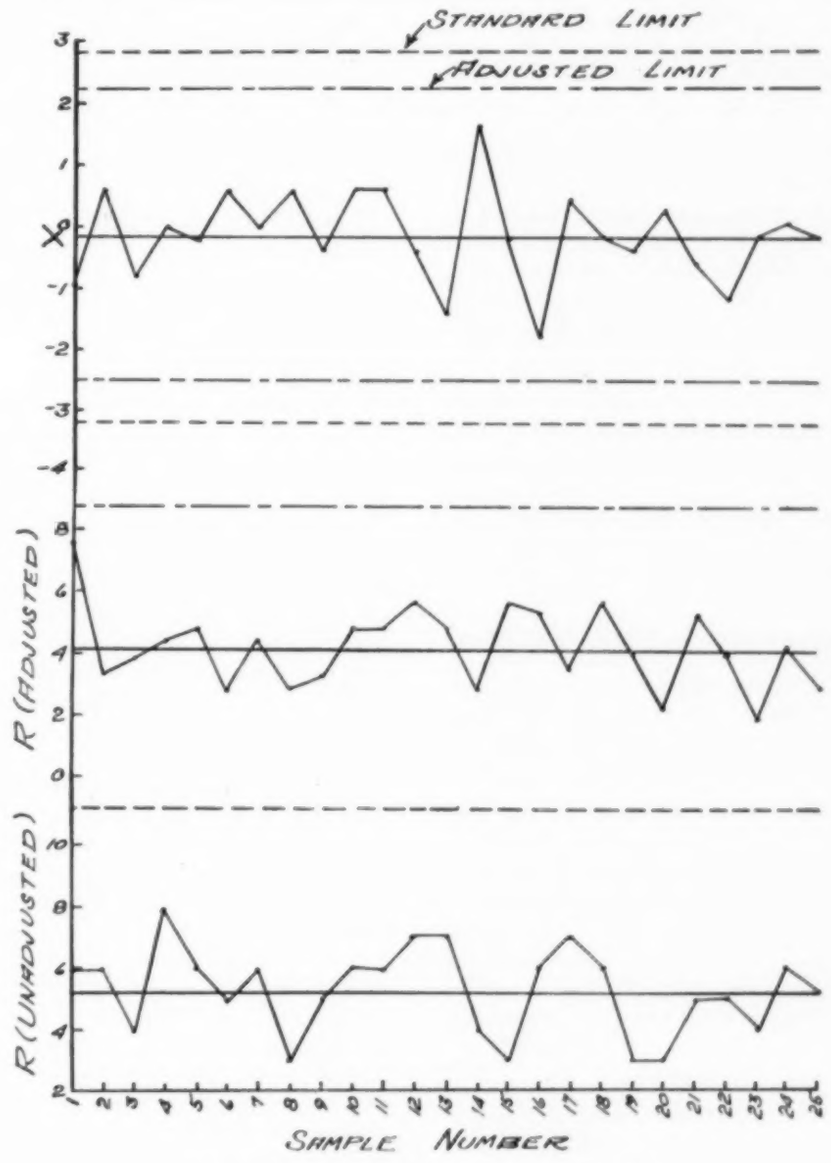


FIGURE 1—CHARTS FOR BINGO CHIP DATA

TABLE IV. WEATHER DATA (DEGREE-DAYS) BEFORE ADJUSTMENT

Month	Heating Season Ending in Year— 1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946
Sept.	76	144	104	80	193	129	209	200	189	154	118	179	231	142	164
Oct.	369	412	508	497	463	475	536	403	484	538	425	431	531	483	524
Nov.	574	857	969	666	740	918	775	717	867	814	692	766	818	756	752
Dec.	962	1065	1264	1222	1294	1021	1144	1056	1066	1075	1020	1240	1192	1210	1252
Jan.	916	968	1208	1340	1296	1039	1307	1291	1443	1305	1248	1403	1093	1549	1209
Feb.	1020	1065	1506	1171	1362	1020	1042	1118	1168	1136	1233	1105	1142	1093	1189
Mar.	1095	1021	1130	901	944	1117	920	1125	1198	1159	906	1098	1135	691	698
Apr.	705	582	691	613	743	647	576	746	701	442	470	795	739	545	621
May	296	225	223	376	230	248	294	255	341	233	289	329	205	468	346
$\bar{X}$	668	704	845	763	807	735	755	768	829	762	711	816	787	771	751

there was a tendency for the sheet to be thicker at the center than at the edges. This was due to the fact that the camber on the rolls was not exactly right for the material being rolled, a condition which is difficult to avoid in practice, since changing the camber is an expensive operation.

The coil averages are plotted in Figure 3 along with standard limits of 182.9 and 190.4 and adjusted limits, as proposed in this paper, of 185.3 and 188.1. It will be noticed that the adjusted limits indicate a lack of control which the standard limits do not.

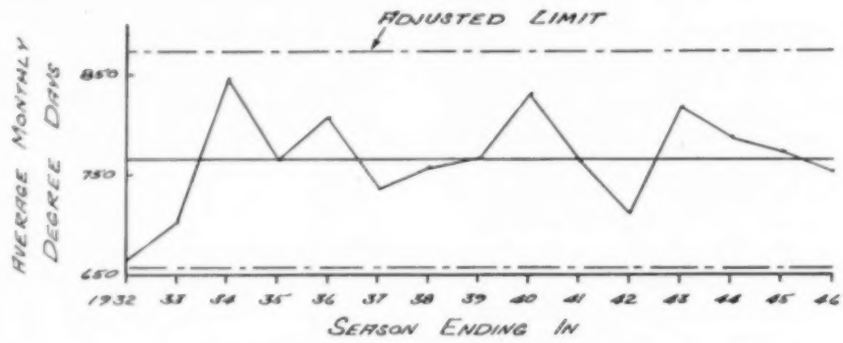


FIGURE 2—$\bar{X}$ CHART—WEATHER DATA

RELATION TO OTHER METHODS

Other methods for dealing with control data having or suspected of having a within-subgroup pattern include the moving range and analysis of variance.

Control limits for charts such as those shown in Figures 1, 2 and 3 could be obtained by treating the $\bar{X}$ values as individuals and using a moving range of two. Such charts would likely detect trends in the data or a sudden change in level but would not detect a random assignable cause operating between subgroups.*

Those familiar with analysis of variance techniques will recognize the within-subgroup pattern of Table I as a "row effect" and the $\bar{X}$ control chart of Figures 1, 2 and 3 as the analogue of a test for significant column effects. The control chart approach provides, in addition, (1) the range chart, (2) a convenient method for picking out a single subgroup that may be out of control, and (3) a convenient method of incorporating future data. In both the analysis of variance and the quality control method, the error term on which the significance test or the control limits, respectively, are based is essentially an interaction, and its use as an error term involves the same assumptions. In most cases where the quality control approach will be used, the subgroups will be replications and the interaction a valid error term. Where only "fixed effects" are envisaged, then the presence of a fixed interaction will make the analysis of variance test less sensitive and, correspondingly, widen the limits on the control chart.

*—If in Table I, columns of algebraic differences are inserted between the subgroups, and ranges for these columns computed, this would appear to be a better way of using moving range. However, this possibility has not been fully explored by the authors.

POSSIBLE EXTENSIONS

Quality control analogues to other analysis of variance techniques can readily be worked out by an extension of the method described in this paper. For example, tests for both column and row effects can be made by using the method of this paper for detecting column effects and then adjusting the original data for column pattern and testing for row effects. Not infrequently, an attempt is made to do this by standard control chart methods with the result that any row effect expands the limits on the column chart, and vice versa.

Similarly, if more than one measurement is available per cell, tests for significant column, row, and interaction effects can be made by averaging the within-cell ranges to give an $\bar{R}$ and using it for computing control limits for (1) column means, (2) row means and (3) cell means adjusted for both column and row means so as to exhibit interaction only. However, most readers will prefer analysis of variance techniques for dealing with data of this kind.

TABLE V. SHEET METAL DATA BEFORE ADJUSTMENT

(Thickness in inches, multiplied by 4000*)

Position	Coil Number														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Left	750	735	745	740	750	755	740	735	750	740	750	735	725	745	750
Center	770	745	765	755	760	765	745	740	760	745	765	745	745	760	770
Right	750	735	745	740	745	750	730	730	750	740	750	730	725	745	750
$\bar{X}$	757	738	752	745	752	757	738	735	753	742	755	737	732	750	757

*For convenience the computations were made with the data as shown and the vertical scale of the control chart divided by 4000 to revert to inches gauge as shown in Fig. 3.

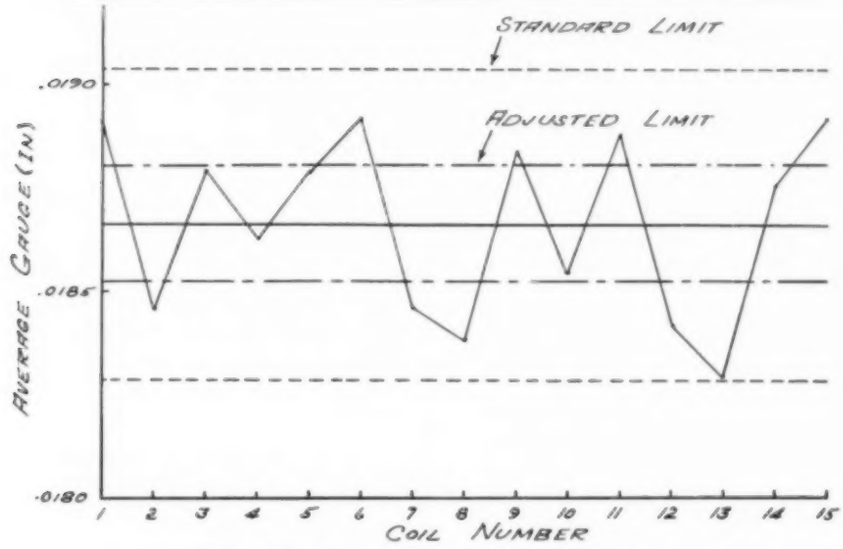
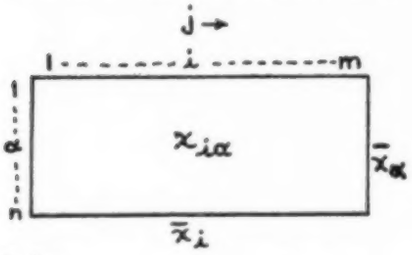


FIGURE 3—$\bar{X}$ CHART—SHEET METAL COILS

APPENDIX
MATHEMATICAL DISCUSSION



Define

$$x_{i\alpha} = \mu + \mu_i + \mu_\alpha + \epsilon_{i\alpha}$$

where the

$$\epsilon_{i\alpha},\ i = 1, 2, \cdots, m,\quad \alpha = 1, 2, \cdots, n,$$

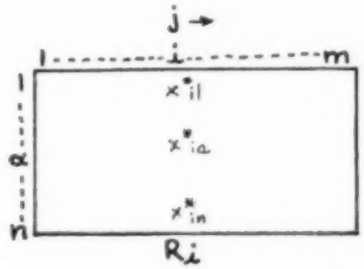
are independent, normally distributed variables with zero means and standard deviations equal to σ'.

Define

$$\bar{x}_\alpha = \frac{1}{m}\sum_{j=1}^{m} x_{j\alpha} = \mu + \mu_\alpha + \frac{1}{m}\sum_{j=1}^{m}\mu_j + \frac{1}{m}\sum_{j=1}^{m}\epsilon_{j\alpha}.$$

Define

$$x^*_{i\alpha} = x_{i\alpha} - \bar{x}_\alpha = \mu_i - \frac{1}{m}\sum_{j=1}^{m}\mu_j + \epsilon_{i\alpha} - \frac{1}{m}\sum_{j=1}^{m}\epsilon_{j\alpha}.$$



Then, for each value of i, the

$$x^*_{i\alpha},\ \alpha = 1, 2, \cdots, n,$$

have the following properties:

1. They are independent, since each of them is composed wholly of numbers from a single row and are, by hypothesis, independent of the numbers in the other rows.
2. They are normally distributed, since they are linear functions of normally distributed variables.
3. The mean of this normal distribution is

$$\mu_i - \frac{1}{m}\sum_{j=1}^{m}\mu_j,$$

which is fixed for each subgroup but may vary from one subgroup to another. (This variation is what the control chart for $\bar{X}$ is intended to detect.)

4. The variance of this distribution is $(\sigma')^2(1 - 1/m)$, since

$$\begin{aligned}\text{Var. } x^*_{i\alpha} &= \text{Var.}\left[\epsilon_{i\alpha} - \frac{1}{m}\sum_{j=1}^{m}\epsilon_{j\alpha}\right] \\ &= \text{Var.}\left[\epsilon_{i\alpha}\left(1 - \frac{1}{m}\right) - \frac{1}{m}\sum_{\substack{j=1 \\ j\neq i}}^{m}\epsilon_{j\alpha}\right] \\ &= \left(1 - \frac{1}{m}\right)^2(\sigma')^2 + \frac{m-1}{m}(\sigma')^2 \\ &= \frac{m-1}{m}(\sigma')^2.\end{aligned}$$

It follows that the range, R_i, of these values is an unbiased estimate of $d_2\sqrt{(m-1)/m}(\sigma')$ and therefore that the average range

$$\bar{R} = \frac{1}{m}\sum_{i=1}^{m} R_i$$

is also an unbiased estimate of $d_2\sqrt{(m-1)/m}(\sigma')$. Thus, in computing limits for the $\bar{X}$ chart, no standard given, ordinary control chart procedure applies,

with d_2 replaced by $d_2\sqrt{(m-1)/m}$, and likewise c_2 replaced by $c_2\sqrt{(m-1)/m}$.

In the range chart, no standard given, the values of R_1 and $\bar{R}$ are compared directly as in the ordinary control chart and no account is taken of the factor $\sqrt{(m-1)/m}$ since the R_1 and $\bar{R}$ are equally affected by it. This range chart differs from the ordinary range chart only through the fact that $R_1, R_2, \ldots R_m$ are not wholly independent, but the effect of their interdependence is so small that it may safely be ignored in practical cases.

In the control charts, standards given, the factor $\sqrt{(m-1)/m}$ is not needed because the σ' specified is the standard deviation of adjusted values, and since the adjustment to be made is specified in advance, the R values on the range chart are independent of each other.

Stratification Control Charts

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1. INTRODUCTION

It often happens in quality control applications that one finds he wants to include in the same sample several measurements arising from somewhat different conditions. For example, a single sample might contain:

(a) Analyses by different laboratories or analysts on a single solution or sample of material.
(b) One piece from each of several machines, taken at the same time of day.
(c) The first, middle and last billet from an ingot of steel.
(d) The castings from several mold cavities from a single cast.
(e) Production figures from three turns for a single day.
(f) Machined rings from base, middle and cap end of a pot.

When samples are taken in such a manner as these examples, however, the variation among the measurements within a single sample will not only be due to random causes, but will also be due to any assignable causes of variation between one condition and another. [Thus in (c) the first billet, in general, does perform differently than the middle billet.] Hence each range tends to be too large and the average range, $\bar{R}$, does not truly reflect random causes only. When this "inflated" average range is used the control band is too broad and hence some very erroneous conclusions can easily be drawn from the conventional control charts.

Because of the difficulty just discussed, it is common practice in quality control instruction to discourage the use of stratified samples such as those mentioned. Instead, the emphasis is placed upon the "rational" sample, in which insofar as possible all the variation is attributed to random causes only. The present paper shows how to make control charts to properly analyze data which are obtained in stratified samples. By use of the technique here explained it will often be desirable to collect data in the form of stratified samples. (There are frequently cases where, in fact, it is impossible to obtain other than stratified samples.) It may well be said that the method to be described can be used to study by control charts, data such as are typical for many analysis of variance problems.

The method will first be illustrated by an actual practical example at Republic Steel Corporation. This will be followed by a brief discussion of some of the mathematical background and finally some further possible applications will be suggested.

EDITOR'S NOTE

This paper and the one that precedes it on "Quality Control Charts for $\bar{X}$ and R Adjusted for Within-Subgroup Pattern" represent two independent and similar solutions of a problem that is of fundamental importance in wide areas of control chart application. The Westman - Lloyd manuscript was received in May 1948; the Burr-Weaver manuscript was received in October 1948.

Because the problem solved and the possibilities for expansion opened up by these papers is of such challenging interest and because each paper makes a distinct contribution to a correct interpretation and application of this new technique, it has seemed best to publish both papers simultaneously so as to present in one issue as broad a view as possible of the subject in its present state of development.

2. A PRACTICAL EXAMPLE

2.1 Process Description—Cold rolled strip is tin-plated electrolytically in a continuous process, the back end of one coil being welded to the front end of the following coil to provide a continuous strip for passage through the process. After passing through tanks containing suitable cleaning solutions, the strip enters the plating tank, traveling at a speed of about 800 feet per minute. This tank contains the electrolyte, or plating solution, and the anodes, suitably shaped bars of pure tin. Deposition of the tin on the strip is accomplished by passing an electric current of proper density through the solution via the anodes, the strip to be plated being the negative pole, or cathode, of an electric cell. The weight of tin deposited is a function of the current density, the speed of travel of the strip, and the distance of the strip from the tin anodes. All other factors remaining constant, it is the latter which will determine the weight of the tin deposit.

Tin plate is produced to specifications giving an average with plus or minus tolerance of "pounds per base box." It is sold on a "base box" basis, the price being dependent on the weight of the tin coating. This unit is really an "area" base, rather than the customary "weight"

TABLE 1. WEIGHT OF TIN-PLATE IN POUNDS PER BASE BOX.

DATE	TURN	OPERATOR EDGE X_1	CENTER X_2	DRIVE EDGE X_3	ORIGINAL DATA SUM	$\bar{X}$	R	ADJUSTED DATA X_1-3	X_2+6	X_3-3	R
5/24	2	70	61	71	202	67.3	10	67	67	68	1
	3	71	64	71	206	68.7	7	68	70	68	2
	3	71	64	71	206	68.7	7	68	70	68	2
5/25	1	75	64	74	213	71.0	11	72	70	71	2
	1	75	64	74	213	71.0	11	72	70	71	2
	1	73	62	70	205	68.3	11	70	68	67	3
	2	72	63	71	206	68.7	9	69	69	68	1
	2	74	65	71	210	70.0	9	71	71	68	3
	3	73	65	72	210	70.0	8	70	71	69	2
	3	74	61	74	209	69.7	13	71	67	71	4
	3	74	66	74	214	71.3	8	71	72	71	1
	3	79	72	78	229	76.3	7	76	78	75	3
5/26	1	66	58	65	189	63.0	8	63	64	62	2
	1	71	60	71	202	67.3	11	68	66	68	2
	1	69	59	65	193	64.3	10	66	65	62	4
	1	79	65	76	220	73.3	14	76	71	73	5
	2	79	67	76	222	74.0	12	76	73	73	3
	2	79	67	76	222	74.0	12	76	73	73	3
5/27	1	73	62	73	208	69.3	11	70	68	70	2
	1	74	61	75	210	70.0	14	71	67	72	5
	2	70	65	74	209	69.7	9	67	71	71	4
	2	70	64	77	211	70.3	13	67	70	74	7
	2	77	66	73	216	72.0	11	74	72	70	4
	3	72	68	72	212	70.7	4	69	74	69	5
	3	72	64	72	208	69.3	8	69	70	69	1
5/28	1	74	71	76	221	73.7	5	71	77	73	6
	1	72	68	72	212	70.7	4	69	74	69	5
	1	72	62	70	204	68.0	10	69	68	67	2
	1	70	65	74	209	69.7	9	67	71	71	4
	1	76	65	74	215	71.7	11	73	71	71	2
	1	75	69	75	219	73.0	6	72	75	72	3
	2	77	67	74	218	72.7	10	74	73	71	3
	2	80	67	77	224	74.7	13	77	73	74	4
	2	71	68	76	215	71.7	8	68	74	73	6
	3	66	59	66	191	63.7	7	63	65	63	2
TOTAL		2565	2258	2550	7373	2457.8	331	2460	2468	2445	110
AVERAGE		73.3	64.5	72.9	70.2	70.2	9.5	70.3	70.5	69.9	3.1
DEVIATION FROM GRAND AVERAGE		+3.1	−5.7	+2.7							
ADJUSTMENTS TO INDIVIDUALS		−3	+6	−3		$\bar{X}$	$\bar{R}$			$\bar{X}$	$\bar{R}$
U.C.L.						79.9	24.4			73.4	8.0
L.C.L.						60.5	0.0			67.0	0.0

Control Limits for $\bar{X}_1$, $\bar{X}_2$ and $\bar{X}_3$: U. C. L. 71.2; L.C.L. 69.3.

base used in most steel products, since a "base box" contains 112 sheets of tin plate 14" x 20", or the equivalent area, regardless of gauge, or thickness, of the sheet.

Obviously, a uniform coating from edge to edge of the strip and from one location in the coil to another, of exactly the ordered thickness is most desirable and most economical. Excessive thicknesses are unnecessary and wasteful, while too little coating does not provide the degree of protection demanded of the tin plate by the processor.

At selected periods a test piece, the full width of the strip, is cut from the process, and is tested for coating thickness. Three spots on each test piece are checked, near both edges and at the center. Based on these results, suitable adjustments in the process are made by the operator. Such test data provide ideal statistics for quality control analysis on uniformity and weight of coating thickness.

Actual test data over a five day period are listed in Table 1 in the columns headed X_1, X_2, and X_3.

CALCULATIONS FOR CONTROL LIMITS

(Data of Table 1.)

Original Data n=3

$\bar{X}$: $\bar{\bar{X}} \pm A_2\bar{R}$
$=70.2 \pm (1.023)(9.5)$
$=60.5;\ 79.9$

R: $D_3\bar{R}=(0)(9.5)=0$
$D_4\bar{R}=(2.574)(9.5)=24.4$

Adjustments

X_1: $\bar{\bar{X}}-\bar{X}_1$
$=70.2-73.3=-3.1=-3$ (appr.)

X_2: $\bar{\bar{X}}-\bar{X}_2$
$=70.2-64.5=+5.7=+6$ (appr.)

X_3: $\bar{\bar{X}}-\bar{X}_3$
$=70.2-72.9=-2.7=-3$ (appr.)
Total $=\bar{0}$

Adjusted data n=3

$\bar{X}$: $\bar{\bar{X}} \pm A_2\bar{R}$
$=70.2 \pm (1.023)(3.1)$
$=67.0;\ 73.4$

R: $D_3\bar{R}=(0)(3.1)=0$
$D_4\bar{R}=(2.574)(3.1)=8.0$

Original position averages n=35

$\bar{X}$: $\bar{\bar{X}} \pm 3\bar{R}/(d_2\sqrt{N})$
$=70.2 \pm 3(3.1)/(1.693\sqrt{35})$
$=69.3;\ 71.1$

(Note that n=3 for d_2 but we use N=35 in $\sqrt{N}$)

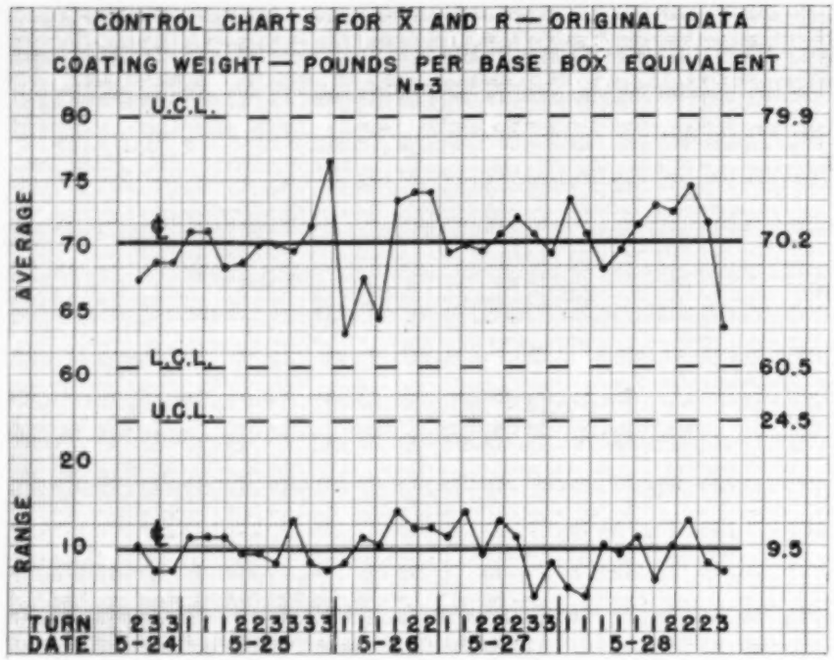

FIGURE 1—COATING WEIGHT CHARTS—ORIGINAL DATA

2.2 Present Procedures — Although the data shown in the columns headed X_1, X_2 and X_3 in Table 1, are in reality stratified samples, ordinary control charts for $\bar{X}$ and for R were constructed. (Control limits were obtained by the well known formulas: $\bar{\bar{X}} \pm A_2\bar{R}$, $D_3\bar{R}$ and $D_4\bar{R}$, with $\bar{\bar{X}}=70.2$ and $\bar{R}=9.5$). As may be seen in Figure 1 the two control charts show exceptionally good control. As judged by control charts constructed in the foregoing manner, therefore, the process would be given a "clean bill of health." Closer inspection of the control charts shows, however, that control is almost "too good." For example, there are no points even close to the upper control limit for ranges, while the $\bar{X}$ chart shows not a single point out of the 35 more than $2\sigma_{\bar{x}}$ away from the center line. Hence the careful worker would

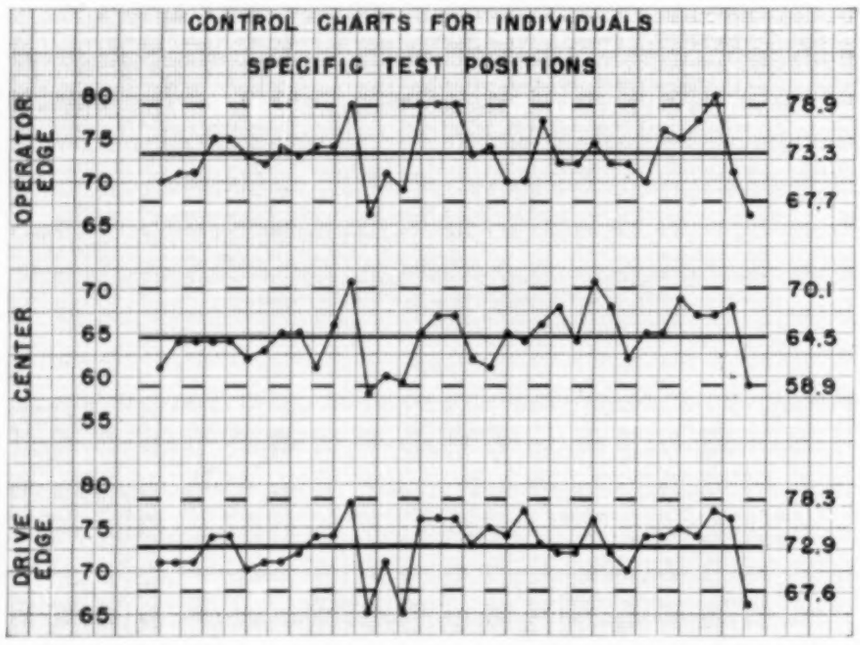

FIGURE 2—CHARTS FOR SPECIFIC TEST POSITIONS

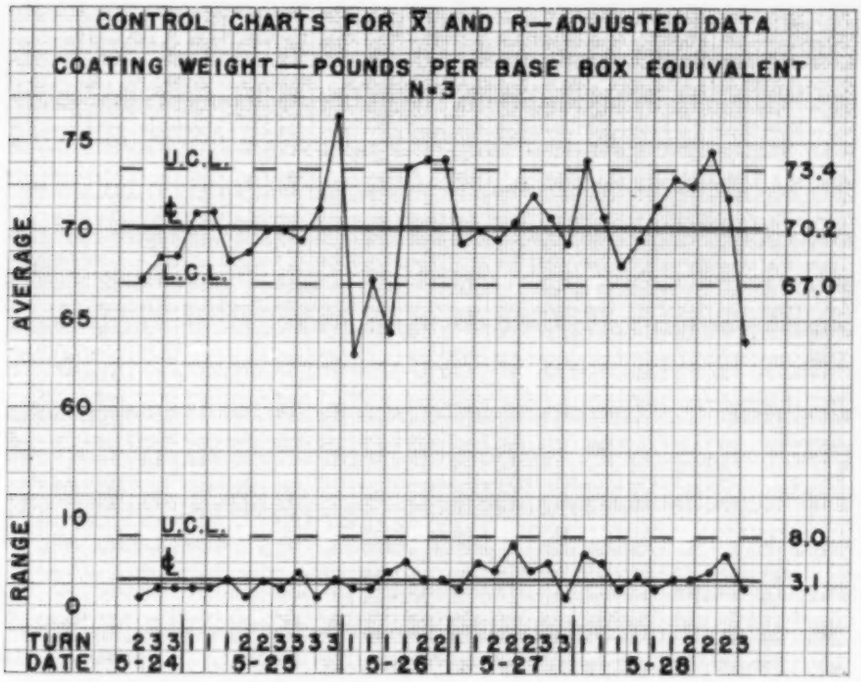

FIGURE 3—COATING WEIGHT CHARTS—ADJUSTED DATA

question the validity of the conclusion. The error of course lies in the fact that in each sample of tests, the results vary not only because of random causes, but also because in general the center test is lower than the other two tests. Thus the range for the three not only reflects random causes but also the assignable cause of difference in coating between center and edge. Thus the ranges are inflated and their average $\bar{R}$ is too large. This causes the control bands of both $\bar{X}$ and R charts to be too wide. Analysis of such stratified data in the foregoing manner is therefore unreliable.

One way out of the difficulty is to make individual control charts for each of the three positions. There are 35 points on each of the charts as shown in Figure 2. The control limits were calculated by moving ranges (first two X_1's then the second and third, etc.) and the formula $\bar{X} \pm 3\bar{R}/d_2$, (where $d_2=1.128$ for the sample size of $n=2$). These three charts show the same general degree of randomness in all three charts, but the chart for the center position is definitely lower than those for the other positions. Although this approach is a good possibility it is undesirable from at least four viewpoints:

(a) A direct comparison between the three positions is not shown.
(b) The information on a single test of three measurements is not summarized by a single point, but is made up of three points on separate charts.
(c) An assignable cause present may so inflate the moving range that the charts miss the assignable cause. Such was the case here.
(d) The control chart for individuals places somewhat more strain upon the assumption of normality than does the control chart for $\bar{X}$'s.

A third possibility, which will at once occur to the statistician, is analysis of variance. Thus we might analyze the entire variability within the 105 numbers shown, into that part due to variation from position to position, that due to variation from strip to strip (time to time) and that part due to random causes (and any other unclassified assignable causes). The results of such analysis of variance are shown in Section 4. Although the analysis of variance approach to this problem has many advantages, it does have the following disadvantages:

(a) Even if the variation from strip to strip proves significant there is no information in the test itself as to just which strip is high or low or whether it is several high and several low or a trend up or down.
(b) A comparison between the average thickness of coating at the three different positions on a strip is not explicitly shown.
(c) Uniformity of variability is not tested.
(d) The calculations, while reasonably easy, especially with a calculating machine, are a little involved for the industrial man whose statistical experience is largely wtih the control chart.

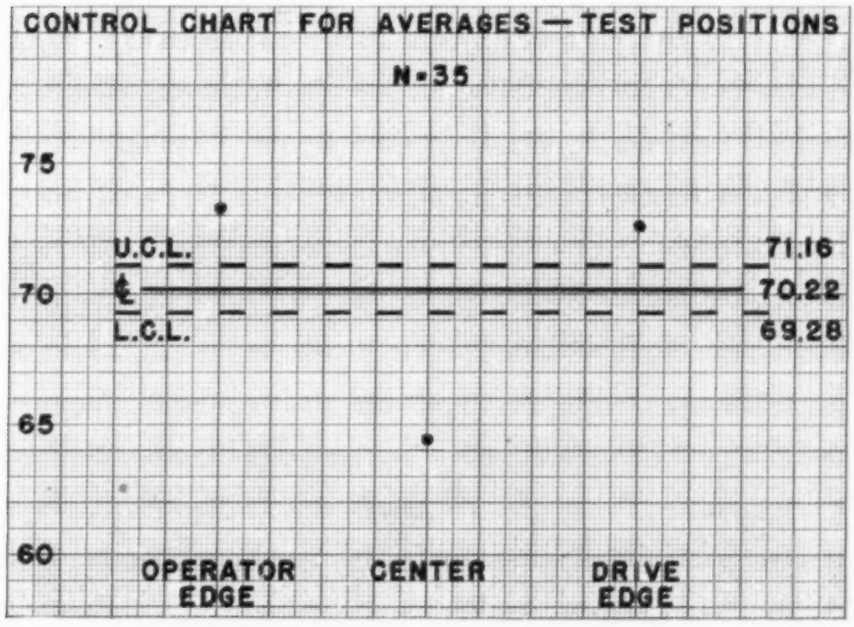

FIGURE 4—CHART FOR TEST POSITION AVERAGES

2.3 New Technique Developed

In order to overcome the disadvantages of analysis of variance just mentioned the following control chart method was developed. The technique would seem to have very wide applicability to data in stratified samples.

The data were first adjusted for the assumed presence of a constant assignable cause which produces lower test readings on thickness of coating at the center of the strip than at the edges as follows:

(a) The average reading at each position and the grand average were found.

(b) The average reading at the center being 64.5 against an overall average of 70.2, each center reading was adjusted upward by 6 units (the nearest whole number to 70.2—64.5). Similarly the other readings were adjusted downward by 3 units each.

Next the adjusted data were analyzed as follows:

(a) Each row was treated as a single sample of three measurements each. Note that the $\bar{X}$'s are the same as the original $\bar{X}$'s since the total of the adjustments in any one row was zero (—3+6—3=0).

(b) Control limits for $\bar{\bar{X}}$ and R for the samples in (a) were found by $\bar{\bar{X}} \pm A_2\bar{R}$, $D_3\bar{R}$ and $D_4\bar{R}$, $\bar{\bar{X}}$ being the same as for the unadjusted data but $\bar{R}$ being considerably smaller, 3.1 as compared to 9.5, for the unadjusted data. The reader should note the two R columns in Table 1.

(c) A control chart for the three different positions was constructed, showing one point for each position, using the column averages for the unadjusted data. The control limits are found by using $\bar{\bar{X}} \pm 3\bar{R}/(d_2\sqrt{N})$ where $\bar{R}$ is the average range for the adjusted data, d_2 is for n=3, and N is the number of tests in each column average, namely 35.

A comparison between Figures 1 and 3 brings to light the fact that although the points on the $\bar{X}$ charts are in the same position, the control band is narrower for Figure 3 and we find five points above the upper control limit and three below the lower control limit. Appropriate investigations should therefore be made of the conditions under which the corresponding strips were produced and tested. The range chart for the adjusted data shows satisfactory control giving us confidence in the stability of random causes of variability. This range chart does not, however, show the "too good" control of the range chart of Figure 1. The chart for averages at each position in Figure 4 shows a very clear-cut picture of the variation in thickness of coating across the strip, since all three points are outside of the control band, the two edges being high and the center low. The true characteristics of the process are thus exhibited and we have a set of control charts which are definitely useful in assisting the control of quality during production, both within test pieces and from one test piece to another.

3. DESCRIPTION OF TECHNIQUE

When measurements appear in a rectangular table in which the various columns represent differing machines, formulas, personnel, etc. and the various rows also represent differing times, material, personnel, etc. then the steps in the analysis are as follows:

(a) Total the columns and rows checking on the grand total.

(b) Subtract each column average from the grand average, thus obtaining amounts by which the X's in each respective column are to be adjusted. These adjustments should be rounded to the same precision as the original data or one more decimal place, preferably the latter. The adjustments should also be made to total zero so that each row total will be the same for the adjusted data as for the original data.

(c) Each X is adjusted by adding the respective adjustment for that column. This has the effect of increasing the measurements in columns with low averages and decreasing those in columns with high averages.

(d) Ordinary control chart technique for $\bar{X}$'s and R's is applied to the adjusted data, each row forming a single sample.

(e) A control chart for column averages of original data is next constructed, with center line $\bar{\bar{X}}$ and control limits at $\bar{\bar{X}} \pm 3\bar{R}/(d_2\sqrt{N})$ where $\bar{R}$ is for the adjusted data, d_2 for n=number of columns, and N the total number of original measurements, X in a column.

(f) Conclusions are drawn from the two $\bar{X}$ charts and the one R chart.

(g) It would also be possible to adjust for row averages rather than for column averages. In general the choice would seem to be a practical one, depending upon convenience and which grouping makes the best practical sense in estimating random variability.

4. MATHEMATICS INVOLVED

The new control chart technique here discussed is closely related to analysis of variance. In fact it is essentially a different use of the same tools and approach. The following calculations by analysis of variance show the total variation divided up into three separate parts: (a) that due to column to column variation, (b) that due to row to row variation, and (c) that which is independent of either. The calculations were done as shown, since this is the easiest approach from the calculational viewpoint. When done in this manner, however, the results do not readily show their true interpretation as sums of squares. Let us focus most of our attention upon Q residual. This quantity is that part of the total variation which is independent of constant assignable causes of both column to column and row to row variation. The analysis of variance technique therefore uses this quantity as a measure of the population variability by making out of it an unbiased estimate of population variance $(\sigma')^2$ through dividing by the appropriate number of degrees of freedom. Now a laborious but highly instructive way to calculate Q residual would be to find the sum of the squares of the 105 residuals each being found by the formula:

$$X—\bar{X}\text{-col}—\bar{X}\text{-row}+\bar{\bar{X}},$$

where we subtract the respective column average and the row average from each X and finally add the grand average. A more meaningful way to write this residual is

$$X—\bar{X}—(\bar{X}\text{-col}—\bar{\bar{X}})—(\bar{X}\text{-row}—\bar{\bar{X}}),$$

which is exactly equal to the preceding. Since these residuals total zero, the sum of the squares is in reality only reflecting the variability of all of them, finally making an unbiased estimate of population variance.

The new technique requires the formation of adjusted data by the formula $X+(\bar{\bar{X}}—\bar{X}\text{-col})$, which is an adjustment for the column each X was in. Then these new figures are not analyzed for variability throughout the table, but instead within each row, using ranges. The results would, however, be just the same as though we were to take the true residuals

$$X—\bar{X}—(\bar{X}\text{-col}—\bar{\bar{X}})—(\bar{X}\text{-row}—\bar{\bar{X}})$$

and use ranges of rows of these residuals. Therefore it is not necessary to do the full job of finding the residuals as last shown, and one can use the adjusted data as discussed before in Sections 2 and 3. The next step is to get the unbiased esti-

mate of population standard deviation by $\bar{R}/d_2$, the formulas given making use of this estimate. It is true, as will be brought out in a more mathematical paper, that there is a little bias in this procedure. Since the bias is relatively negligible even for quite small numbers of rows and columns it is not worth bothering about in most industrial applications.

It is worth noting that the two estimates of σ' based upon residual or random cause variation are nearly equal, for the illustrative data.

By the analysis of variance we have

$\sigma' = \sqrt{(Q\text{-residual})/(2)(34)}$
$= \sqrt{240/68} = 1.88,$

while using $\bar{R}$ from the adjusted data we have

$\sigma' = \bar{R}/d_2$
$= 3.14/1.693$
$= 1.85.$

5. SUGGESTED APPLICATIONS

In addition to the possible applications in Section 1 the following may be of interest:

(a) Weighing operations; different people or machines at various times.

(b) Different types of jets on several runs, using all jets on each experimental run.

(c) First, middle, and last sample on several batches.

(d) Performance of measuring technique or device on several different samples.

(e) Shift performance day by day.

(f) Different lots of material on each of several machines.

(g) Temperature readings from several thermostats at varying times.

(h) Printing performance on various papers with different inks, types, or presses.

(i) Performance of employees on various tasks of similar nature.

(j) Ratings of jobs by different raters.

4.1 ANALYSIS OF VARIANCE CALCULATIONS

$\Sigma\Sigma X^2 = 70^2 + 71^2 + 71^2 + \ldots + 62^2 = 520{,}565$

$(\Sigma\Sigma X)^2 = (2565 + 2258 + 2550)^2 = (7373)^2 = 54{,}361{,}129$

$\Sigma(\text{Column totals})^2 = 2565^2 + 2258^2 + 2550^2 = 18{,}180{,}289$

$\Sigma(\text{Row totals})^2 = 202^2 + 206^2 + 206^2 + \ldots + 191^2 = 1{,}555{,}839$

$Q = \Sigma\Sigma X^2 - (\Sigma\Sigma X)^2/105 = 520{,}565 - 7373^2/105 = 2840$

$Q\text{-col} = \Sigma(\text{Col. totals})^2/35 - (\Sigma\Sigma X)^2/105 = 18{,}180{,}289/35 - 7373^2/105 = 1712$

$Q\text{-row} = \Sigma(\text{Row totals})^2/3 - (\Sigma\Sigma X)^2/105 = 1{,}555{,}839/3 - 7373^2/105 = 888$

$Q\text{-res.} = Q - Q\text{-col} - Q\text{-row} = 2840 - 1712 - 888 = 240$

$A = (Q\text{-col})/2 = 1712/2 = 856$

$B = (Q\text{-row})/34 = 888/34 = 26.1$

$C = (Q\text{-res.})/68 = 240/68 = 3.53$

$F = A/C = 856/3.53 = 242$ $\qquad$ $F = B/C = 26.1/3.53 = 7.4$

$F_{.01} = 4.93$ $\qquad$ $F_{.01} = 1.95$

REPORT OF

Fifth Annual Rochester Clinic

The Fifth Annual Rochester Quality Control Clinic was held on Tuesday, February 15, 1949 in Rochester, New York, at the Chamber of Commerce. This all day Clinic was sponsored by the Rochester Section of ASQC in cooperation with the Industrial Management Council of Rochester. Considerably more than 300 persons attended all or parts of the day's activities.

At the noon luncheon meeting, Mr. Paul H. Rutherford, General Manager of the Delco Appliance Division, General Motors Corporation, Rochester, spoke on the subject "Quality Control in a Competitive Market." Mr. Rutherford declared that "Management looks to Quality Control for two things—sane and reasonable approach toward quality requirements and a real cost consciousness."

Mr. K. A. Brownlee, who is associated with the Development Division of E. R. Squibb and Sons at New Brunswick, New Jersey, spoke at the Fifth Annual Dinner in the evening. Mr. Brownlee, whose subject "Experiments Show the Way," cited from his own experience the very effective manner in which statistical quality control was applied to certain problems in explosives in England during the War. The speaker further described the use of similar techniques for the purpose of increasing penicillin production.

MR. K. A. BROWNLEE

The afternoon program consisted of seven clinic sessions as listed below. The entire series was given twice, once from 1:30 - 3:30 and again from 3:30 - 5:00.

CLINIC 1

SUBJECT: "Control Charts"

SPEAKER: Dr. Martin Brumbaugh,
Director, Dept. of Statistical Analysis,
Bristol Laboratories, Inc.
Syracuse, N. Y.

(Continued on page 18)

ANNOUNCING THE

Third Annual Convention
American Society for Quality Control

COPLEY PLAZA HOTEL, BOSTON, MASSACHUSETTS

SERIES A

"Quality Control Engineering"
A Two Day Practical Course

An attack upon the problems of any plant; five sessions.

The engineering and administration phases of a quality control problem will be covered. A panel of three qualified men will discuss many new practical statistical techniques along with the conventional control charts and sampling plans. The discussions will start almost from scratch—but instead of theory, you are in for some practical advice gathered from experiences in the manufacturing and gaging industries, consulting, and educational fields.

CHAIRMAN

Dorian Shainin, Chief Inspector
Hamilton Standard Propellers

COMMITTEE MEMBERS

O. H. Somers
Western Printing & Lithographing Co.
Poughkeepsie, N. Y.
Professor Paul Peach
Institute of Industrial Statistics
North Carolina State College
University of North Carolina

Thursday A.M — 1st Session
Incoming and batch inspection.

Thursday P.M. — 2nd Session
Control of quality in component manufacture.

Thursday P.M. — 3rd Session
Inspection of continuous production and assembly operations.

Friday A.M. — 4th Session
The human element problem and over-inspection.

Friday A.M. — 5th Session
Special engineering investigations
Main speaker - Paul Peach.

SERIES B

"Management's Problems of Quality"

Thursday A.M. — 1st Session
"Mobilizing for Quality in a Competitive Market"
Professor Joseph M. Juran
Administrative Engineering
New York University
Importance of overall, consistent quality policy.

Thursday P.M. — 2nd Session
"A Sound Program for Improving Vendors' Quality"
E. M. Schrock
Quality Control Engineer
General Electric Co.
Vendor certification - understanding specifications - building quality confidence - setting vendor-buyer standards.

Thursday P.M. — 3rd Session
"Building Sales through Quality Control"
S. H. McKibben
Sales Engineer
Corning Glass Works
Quality assurance as a selling point; sales acceptance; overcoming sales resistance.

Friday A.M. — 4th Session
"Building a Quality-Minded Organization"
R. F. Hurst
Assistant to the Vice-President of Manufacturing
Bigelow-Sanford Carpet Co.
Quality psychology; instilling quality thoughtfulness on all levels; setting a firm foundation for real action.

Friday A.M. — 5th Session
"Gaging Consumer Reaction to Product Performance"
Ephrian Freedman
Director
Macy's Bureau of Standards
Macy's experience in determining what the customer wants and how well he likes what he gets.

SERIES C

"Advanced Techniques"
Of Interest to Those in Quality Control

Thursday A.M. — 1st Session
"Diagnosis with Diagrams"
L. A. Seder
Chief Quality Control Engineer
Gillette Safety Razor Co.
Picturing product variability; a unique means for presenting quality data.

Thursday P.M. — 2nd Session
"Practical Applications of New Theory: A Review"
Professor Frederick Mosteller
Harvard University;
Dr. John Tukey
Princeton University
Summary of latest developments in mathematical statistics clearly presented for use in Quality Control.

Thursday P.M. — 3rd Session
"What Risks Should I Take in Sampling Inspection?"
F. E. Satterthwaite
Quality Control Engineer
General Electric Co.
Role of experience in setting up a sampling plan.

Friday A.M. — 4th Session
"Presentation of Measurement and Product Variability"
F. E. Grubbs
Chief, Surveillance Branch
Research Laboratory
Aberdeen Proving Ground
How to get at product variation independently of instrument errors.

Friday A.M. — 5th Session
"Some New Sampling Plans for Continuous Production"
H. F. Dodge
Quality Results Engineer
Bell Telephone Laboratories
New techniques for conveyor line sampling.

AND THE

Third New England Quality Control Conference

THURSDAY AND FRIDAY, MAY 5-6, 1949

SERIES D

"Selected Topics of Special Interest"

Thursday A.M. — 1st Session

"Dimensions and Tolerances, the Foundation of Quality Control"

Professor Earle Buckingham
Massachusetts Inst. of Technology

Among other things, an explanation of the new and widely discussed English dimensioning system.

Thursday P.M. — 2nd Session

"Gage Standardization Rooms"

C. H. Borneman
Supervisor Tool & Gage Service
General Electric Co.

Proper control of the Quality Standards.

Thursday P.M. — 3rd Session

"Analyzing and Channeling Inspection and Quality Control Information"

G. A. Fort
Quality Control Engineer
The Parker Appliance Co.

Curing quality troubles by streamlining your paper work.

Friday A.M. — 4th Session

A panel Discussion—"The Quality Control Department as a Training Ground for Supervisory Personnel"

Chairman: E. H. Robinson
Director of Quality Control
Johnson & Johnson

Panel: E. D. Thompson
Works Manager
Badger Meter Co.

Harris Reinhardt
Manager of Employment and Training
Sylvania Electric Products, Incorporated

E. S. Gibian
Chief Industrial Engineer
Thompson Products, Inc.

Friday A.M. — 5th Session

A Panel Discussion—"Latest Thinking on Quality Control Education"

Chairman: Professor Lloyd Knowler
Chairman of Mathematics Department
University of Iowa

Topic: "In-plant training courses"
Wade R. Weaver
Metallurgical Engineer
Republic Steel Corp.

Panel: Arthur Bender, Jr.
Delco-Remy Division
General Motors Corp.

Topic: "Courses sponsored by local Quality Control Societies"

R. E. Wareham
President, ASQC

Topic: "Quality Control education by a consultant"

Professor Irving Burr
Purdue University

Topic: "Undergraduate courses"

Mason E. Wescott
Editor, INDUSTRIAL QUALITY CONTROL

Topic: "Quality Control education through publications"

CASE HISTORIES OF QUALITY CONTROL IN SPECIFIC INDUSTRIES

FRIDAY AFTERNOON — MAY 6th

CLINIC 1—Amorphous Products Industries

Rubber: J. W. Morrison
U. S. Rubber Co.

Plastics: J. Adams
Monsanto Chemical Co.

CLINIC 2—Batch Products Industries

Chemical: W. L. Gore
E. I. duPont deNemours & Co.

Food: E. C. Farmer
H. P. Hood & Sons

CLINIC 3—Electrical Industries

Apparatus: A. A. Goodman
Westinghouse Electric Corporation
Steam Turbine Division

Lamps: P. M. Dickerson
Westinghouse Electric Corp.
Lamp Division

CLINIC 4—Continuous Process Industries

Textile: R. H. Souther
Cone Mills

Paper: Carl E. Noble
Kimberly-Clark Corp.

CLINIC 5—Mechanical Industries

Forging: James Rayer
Timken Detroit Axle Co.

Aircraft: J. G. Rutherford
Glenn L. Martin Co.

CLINIC 6—Job Shops

H. Edgerly, Scott & Williams, Inc.
Irving Schiesel, Mattatuck Mfg. Co.

Thursday Luncheon
SPEAKER: Mr. A. B. Holmstrom
Vice President Norton Co.
Worcester, Massachusetts

Friday Luncheon
SPEAKER: To be announced

Thursday Evening: ANNUAL CONVENTION DINNER MEETING, ASQC
SPEAKER: Edward Gluck, Lt. Colonel, Ordnance Department
Deputy District Chief, New York Ordnance District.
SPECIAL CEREMONY: Awarding of First Shewhart Medal to the 1948 Medalist.

ROCHESTER CLINIC

(Continued from page 15)

CLINIC 2

SUBJECT: "Quality Control as a Chemical Engineering Tool"

SPEAKER: Dr. George N. Cornell
Chief Chemical Engineer
A. E. Staley Mfg. Co.
Decatur, Illinois

CLINIC 3

SUBJECT: "Is Receiving Inspection a Liability or an Asset?"

SPEAKERS: Edward Close, Chief Inspector, Instrument Division
Bausch & Lomb Optical Co.
Rochester, New York

Wilson B. Wight
Assistant Purchasing Agent
Bausch & Lomb Optical Co.
Rochester, New York

CLINIC 4

SUBJECT: "Design of Experiments"

SPEAKER: Dr. Grant Wernimont
Quality Control Engineer
Color Control Department
Eastman Kodak Company
Rochester, New York

CLINIC 5

SUBJECT: "Statistical Analysis of Field Complaints"

SPEAKER: Prof. W. A. MacCrehan
Administrative Engineering
Director of Gage Laboratory
New York University
New York City

CLINIC 6

SUBJECT: "Services of the University Ordnance Gage Laboratory to Industry"

SPEAKER: Mr. Ben Patton
Chief of Gage Laboratory at Frankford Arsenal
Philadelphia, Pa.

CLINIC 7

SUBJECT: "Reporting Quality to Management, Customer and Suppliers"

SPEAKER: Mr. Fred C. Schulze
Chief Inspector
Hunter Spring Co.
Lansdale, Pa.

Sampling for Lot-Quality Contrasted with Predicting an Election

W. EDWARDS DEMING

BUREAU OF THE BUDGET, WASHINGTON, D. C.

SAMPLING FOR LOT QUALITY

In any acceptance-sampling plan, there is a producer's risk and a consumer's risk. In the use of $\bar{X}$ and R charts there are likewise two risks, viz., being sent on a chase for trouble that does not exist, and failing to look for trouble that does exist. Similarly, there are two risks in drawing a conclusion from any experiment. It is possible in many but not all circumstances to design sampling plans in which the theory of probability may be used to control these risks, and to do so at the least possible cost. In fact, the statistician's job seems to be mainly the use of the theory of probability to minimize the net economic losses arising from two kinds of errors. A **statistical** plan is distinguished by this **minimum net loss.**

One of the most important problems of quality control is **how to sample a lot** of material to determine its quality. Two risks are involved in this problem also:

1. A sampling plan may furnish too much precision, and thus be too costly and time-consuming.
2. It may fail to furnish enough precision, and lead to bad feelings or even a lawsuit.

In a statistical plan these errors are controlled through **sample-design,** a subject that has been carried far in social and economic surveys, in the Census, Bureau of Labor Statistics, Bureau of Agricultural Economics, Bureau of Customs, and in many other places, notably in England and India. These methods depend on the theory of probability and on field work so faithfully carried out that the theory of probability may be applied. Adaptation of these methods into the sampling problems of industry, along with new original research, are capable of effecting huge savings, with improved assurance of quality determinations.

Before one can say that any sampling plan furnishes sufficient or too much precision, it is necessary to set a goal: what precision is wanted? The more precision demanded, the greater the cost; hence it pays to specify as low a precision as tolerable. An answer may be provided for illustration by specifying that the standard error of the sample (percent ash; B.t.u. content; minimum breaking strength; clean content of wool; weight of a shipload of sugar, tobacco, or wool) taken from a lot shall be ½%. This would correspond to a 3-sigma band of 1½%, outside of which practically no sample would ever fall. Wider limits may and will be specified to suit the requirements. Sometimes the criterion to be met is one of cost; the cost of sampling a lot may not exceed (e. g.) $100, in which case the sampling problem is to obtain the greatest possible precision for the allowable cost.

OPINION SURVEYS AND SAMPLING FOR LOT QUALITY

The recent failure of the polls has been the cause of many letters and editorials in newspapers, in some of which all sampling is consigned to perdition. One great and lasting benefit of this publicity is the interest that has been created in **statistical methodology.**

It may not be apparent at first sight that many of the problems in forecasting an election are identical with certain statistical problems in quality control, particularly the problem of how to sample a lot. It is also true that some problems of election-forecasting are not statistical, but involve judgment, subjectively. It is important that anyone engaged in quality control should attempt to understand these similarities and differences.

Social and economic and opinion surveys correspond to a determination of lot-quality. In such surveys, in modern practice, there will be a prescribed precision, such as to estimate with 3-sigma limits of (e.g.) 5 percent, what would be the results of a complete coverage taken to discover how many people in a certain area are seeking work, how many worked 25-29 hours last week, how many dwelling units are vacant, the expenditure pattern for food or clothing, industrial employment, acreage in wheat, condition of crops last week, or an opinion pattern. There are economical and uneconomical ways of performing such surveys; there are biased and unbiased ways; and the same statements hold for sampling lots. The statistician's job is to meet the precision required, but not to over-do it, and to demonstrate beyond question the magnitude of his errors.

In order to understand what has happened to the polls, it is important to recognize at least three distinct steps in a sampling problem. **First** comes the **definition of the universe** (the lot). If a complete canvass were to be made, i. e., if there were no problem of sampling, who would be canvassed? All adults? All people who will be legally eligible to vote on election day? All people who will vote? (We shall return to this in a moment.) **Second,** a meaningful **questionnaire** the (test-method) must be devised to throw light on the aims of the survey—in this instance, the prediction of an election. **Third,** the **sample**—how to do the job at the lowest cost without canvassing everybody (testing every piece). In election polling the sampling problem might be how to estimate with a prescribed accuracy from a relatively small sample how many people or how many voters in the whole country or perhaps in the several states would, if canvassed, say in response to a particular questionnaire that they voted this way or that way or no way in the last election, and now express this or that preference, intensely or apathetically. Besides the steps specifically enumerated here, there are a host of others also, such as the selection, training, and assignments of the interviewers (inspectors); the control of the field work (the sampling and testing); the definitions and classifications to be adopted; the coding and tabulations.

When the aim is merely to collect information regarding the quality of a lot, or about the characteristics of the people or the housing units of a city, the problem ends and the results are published or at least transmitted to the people who want the results.

But here a vital fourth step begins, viz., the interpretation of the data—what disposition to make of the lot, and what changes to make in the process. In election-forecasting, the interpretation involves a prediction which must be made **before the election.** This prediction will be made on the basis of an advance inventory of opinions (the lot-quality) and with the aid of other relevant knowledge and judgment. The interpretation of data is never so objective as the collection of the data. However, the difficulties of interpretation do not provide excuses for inferior workmanship in the methods of survey (determination of lot-quality).

Inferior workmanship in any one of the major steps of taking a survey impairs the reliability and the usefulness of the results, and invites failure of a prediction based on them. In which step or steps did the recent failures of the polls occur? Were the methods of prediction unreliable or were the predictions based on poor data, and were there other troubles? The whole matter has been reviewed by a committee appointed by the Social Science Research Council and it is only necessary to summarize and comment on their report.

What is needed for the prediction of an election is the opinions of people who are going to vote. How can you tell whether a man is going to vote? Given $30,000,000 and unlimited manpower for an opinion-poll so that I could take a complete census of the Continental United States, I should still wonder how to instruct interviewers in the art of recognizing every eligible voter in a household. Because of the difficulty of recognizing the universe of voters, no sample of adults on Monday, not even a complete canvass, could provide the basic data representing the intentions of the voters as they look forward to the election on Tuesday.

Even were this difficulty removed, there would still be a gap in the prediction of an election because voters have the privilege of changing their minds. It is important to make clear to the public that at the present time this gap must be filled in large measure by judgment and subjective methods.

This assertion, however, is not meant to imply that forecasting is not necessary or respectable, but that frequently the methods that must be used are simply **not statistical.** It may well be that the most important problems of administration in both government and industry require prediction of what people are going to do—what they will purchase, where and how long they will live, and even how they will vote. In fact, I have a suspicion that the social and economic problems that require prediction of what people are going to do are in general the really glamorous and attractive ones—also the dangerous ones.

I believe that publicity emphasizing the difficulties of forecasting an election, and making a clear separation between forecasting and eliciting information on which to forecast, will go a long way toward building up public confidence in sampling surveys if not in opinion-polling as well.

SAMPLING A HUMAN POPULATION

In the previous paragraphs I have tried to emphasize the fact that a good sample can not alone solve all the problems of forecasting an election. However, a good sample would help. In many statistical surveys the uses of the data are fairly objective, and a reliable sampling procedure may be essential. This is certainly so when the estimation of the quality and weight of a lot of material determines, for example, the price of the lot or the duty to be paid on it. Nothing but reliable sampling procedures should be tolerated in monthly or periodic information obtained and published by government bureaus regarding employment, unemployment, housing, prices, conditions of crops, business activity, expenditure patterns, and many other statistical series on which the intelligent administration of government and business largely depend.

With regard to the sampling of a human population, a number of points may be of interest. As the pollmasters and much but not all market research have depended on quota sampling, a few words should be said to distinguish quota sampling from the statistician's probability sampling which has been developed in other fields. **First,** quota sampling is accomplished through exercise of the interviewer's judgment, and it is therefore subject to the biases of selection, availability, and definitions of the quotas. The importance of these biases can only be conjectured, as to date, no real effort has been made to measure them or to provide underlying theories for explaining them. Another source of error in the quota method is its dependence on census and other information for multiplying the proportions obtained

in the sample: obsolescence of this information is carried into the final results. A probability sample may be designed to walk on its own feet, without the use of presumably known totals.

Second, when probability samples are used, the sampling errors are under control and are measurable. After the results of a probability sample are in, and the estimates made, the range of sampling variability may be calculated, **not** by comparing the results with known census figures or by observing whether they look to be about right, but by calculations from the returns themselves. If the results, from the point of view of sampling, are wide of the mark that would be hit by a complete canvass, this fact is clearly indicated, and the user is warned not to be cocksure of his interpretations. On the other hand, when the sampling variability is small, the user may have confidence in his basic figures. A probability sample may also be designed so that various other measures of quality are obtained at the same time, other than the sampling errors, such as the possible range of error arising from differences between interviewers, different methods of training them, or between different versions of the questionnaire.

Third, in a probability sample **predetermined rules** govern both the selection of the respondents **and** the procedure of computing the estimates for the universe. The results are not weighed this way or that way, according to judgment. Any method of survey into which judgment enters either in the selection of the respondents or the procedures of estimation will give results whose sampling precision can neither be controlled nor measured. Any such method is not safe where unbiased samples and an index of precision are essential.

Modern statistical research has disclosed some amazing facts about sampling. Filling quotas is not enough. It is possible, for example, by adding a few names here and subtracting some there, to build up a "perfect cross-section" in which various geographic, age, sex, economic, educational, and other classes agree very well with those of the whole population, but which is nonetheless a dismal failure with respect to the questions asked in a particular survey that someone is paying for (Ref. Gini and Galvani, Annali di Statistica, serie vi, vol. 4, 1929). A way out is furnished by the statistical tools of randomization, stratification, methods of estimation, and design of experiment, as used in modern sample-design.

The cost of two surveys cannot be compared merely by comparing the price per interview or by comparing total costs. There is no satisfactory measure of price without a simultaneous index of quality. A probability sample furnishes the required index of quality of the sample.

However, once again, a probability sample will not get around the difficulties of recognizing voters in advance, last-minute changes, or proper design of the questionnaire, all of which arise when data on opinions are used for making a prediction. I would be the last one to say that if the pollmasters had used probability sampling, their troubles would all be over. However essential probability sampling may be for government statistics and for much private research as well, the pollmasters, as I tried to indicate at the beginning, would still have had plenty of problems left over even if they had used probability samples.

There is no reason to be discouraged about future opportunities for the use of sample surveys. Without sample surveys, administrators in government and business would have to make decisions without the aid of periodic information on the labor force, volume of employment, turnover, prices, sales, cause of death, and a host of other population and agricultural characteristics that are considered vital in the administration of government and private business. No one is in favor of making decisions in a vacuum. Good sample surveys are here to stay.

Modern Measuring Instruments in Quality Control*

FRANK W. BLANCHETTE

SALES ENGINEER IN CHARGE OF GAGES, MOORE PRODUCTS COMPANY

ACKNOWLEDGMENTS

The author acknowledges the use of the photographs and the cooperation of The Sheffield Gage Corporation, Federal Products Corporation, General Electric Company, Jones and Lamson Machine Company, and Pratt & Whitney Division Niles-Bement-Pond Company.

* Delivered before The Philadelphia Section, ASQC, Temple University, January 23, 1948

INTRODUCTION

Before reviewing the principles of operation and the methods of application for the comparator method of measuring, it is necessary to understand the reasons for large scale installations of these apparently expensive devices.

Consider the fact that go and no-go plugs, snaps, and similar functional gages, costing in the neighborhood of ten to fifty dollars, are more and more often being replaced by comparators costing as much as two or three hundred dollars. It is obvious that the greater expenditure must be justified before management approves the necessary appropriation for the installation of these modern measuring instruments.

Not too many years ago, and even today in some plants, inspection was considered a necessary evil—a department whose sole duty was to sort good from bad. To have given this type of inspection department an accurate measuring instrument worth hundreds of dol-

lars was inconceivable—especially when the machining operation was being governed by seemingly inexpensive functional gages with all their inherent variables. This purchase would have meant that the percentage of rejections at the point of inspection would have been increased greatly. Under the procedure of machining and sorting by feel with the questionable go and no-go type gage, one can naturally understand the reasons for the numerous discussions which arose daily on the acceptability of the material produced. The elements of human feel, progressive wear, and cleanliness of the parts being measured were all factors which could not be compensated and, therefore, were an important consideration of the final outgoing quality-level.

The introduction of quality control methods in recent years has shown definite savings. Controlling quality of parts in process has greatly reduced the percentage of scrap material. Deviations from desired quality standards are immediately observed and machine tool equipment is promptly corrected. Inspection departments are establishing floor inspection for spot checking production, thereby acting as policemen rather than sorters of the completed components.

To control the quality of material in the various phases of production, it is necessary that any gaging inaccuracies be eliminated completely. It is for this reason that quality control departments have insisted on the installation of modern measuring instruments that suit the individual application. Mechanical, electric and electronic, pneumatic, and optical comparators form the greater percentage of instruments which answer every requirement for accuracy, dependability, and lower ultimate cost.

The comparator method of measuring compares unknown physical dimensions of the work-piece to dimensions established by reference master standards. Minute tolerances can be magnified greatly, thus enabling observations of precision variations at the production point. This visual amplification gives a sense of broad expanse to tolerances, which has resulted in recent years in the development of some very fine machine-operator technique. Because comparators can be set exactly to full blueprint tolerances, greater license can be taken with the tolerance range—a condition impossible with functional members because of wear factor allowances, human feel variables, etc. This procedure has resulted in longer cutting tool, grinding wheel, and honing stone life. The comparator has eliminated the human element in accurary of gaging. The snap could be forced, the plug could be wrung, vernier calipers and micrometers could be sprung. The desired or controlled measuring pressure that is so essential in accurately measuring under ten thousandths, more or less, is built into comparators and does not depend on operator's skill.

MECHANICAL COMPARATORS

The mechanical comparator is the most common type of measuring instrument found in use today. Its flexibility and range make it a universal tool in every machine shop. The gaging head is usually a sensitive, rugged, high quality dial indicator mounted on a sturdy column, supported by a base. The head may be adjusted over a wide range by direct hand location, with final adjustments made possible by means of a precision screw thread adjustment. The dial indicator magnifies the movement of the spindle, usually by means of a gear and pinion, and diverts this movement into an additional magnified swing of the indicating pointer on the scale. The scale is generally of the balance type, reading both left and right of zero, thereby measuring deviations in size, both plus or minus, from basic. A typical Dial Indicator is shown in Figure 1.

The contact point on the spindle may be a variety of shapes and can be supplied with chromium, tungsten-carbide, sapphire, or diamond tips. In mechanical comparators which use dial indicators of conventional design, the magnification is limited to approximately seven hundred times. This is due to the possible errors in the mechanism which are greatly increased with extreme amplification. The mechanical comparator shown in Figure 2, for instance, is not a complete gage in itself, a fact which is also true of all types of comparators. The use of a reference master is necessary to set and calibrate to basic size. Once set, the calibrator will indicate direct variations from basic size.

The dial indicator has been adapted to many varied uses in the comparator field by using different accessories designed for specific applications. For example, when combined with a snap type fixture, the dial indicator serves as a portable O.D. comparator. This type is shown in Figure 3. Used as a component with telescoping or retractable points and lever transmission, the dial indicator becomes an internal comparator.

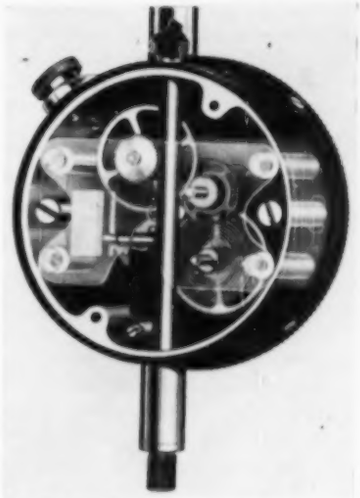

FIGURE 1—DIAL INDICATOR

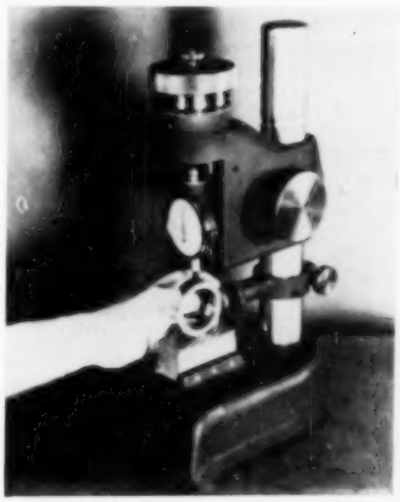

FIGURE 2—MECHANICAL COMPARATOR WITH MICROMETER VERTICAL ADJUSTMENT IN DIAL INDICATOR

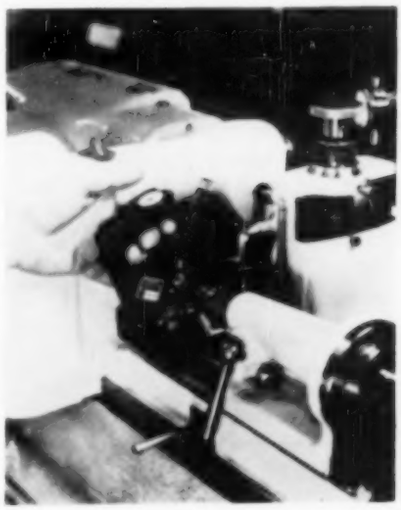

FIGURE 3—INDICATING SNAP

The mechanical mirror-type instrument is similar in every respect to the mechanical dial comparator, except that the gaging head employs a tilting mirror, as shown in Figure 4.

The gaging head overcomes the limitations of wear. Magnification, without sacrifice of accuracy, is made available by the use of an optical light-beam which is passed through lenses and reflected by a mirror onto a scale. The part to be measured (1) rests on the table (3) against the back stop (4). The size of the work piece controls the motion of the spindle. This spindle raises the lever which pivots and lowers arm (10) controlling the position of the tilting mirror (9). The light source (8) is focused to a spot on the mirror, which reflects the spot on to a translucent screen, where it appears to the operator as a disc of light. Across the center of the disc is a dark line which indicates the actual dimension. The usual procedure, however, is to set tolerance limit pointers, using plus and minus masters, to the full travel of the disc in either direction. Work pieces must then conform within these limits. The magnification of this gage is one thousand to one, and the scale is usually six inches long, indicating a spindle motion of six thousandths of an inch. Since the amount of motion is slight and the number of moving parts is held to a minimum, this type of comparator has been used successfully over relatively long periods of time without inaccuracies due to wear. Since the lever arm is a pivoting motion without a preloaded spring tension, the indicating spindle pressure is greatly reduced, providing greater sensitivity in the measurement of thin walled parts.

THE REED METHOD OF MOTION TRANSMISSION

The reed principle of motion transmission has developed still greater fields for mechanical comparators. We have seen so far that mechanical comparators have been confined to the low magnification fields and, as a result, their use in measuring to one ten thousandth of an inch and smaller has been restricted. With the introduction of the reed principle, however, magnifications up to twenty thousand to one have been achieved on standard units when this principle is combined with an optical system of magnification. (See Figure 5.) The reed mechanism as shown in Figure 6 is a simple, frictionless device for magnifying small motion of the spindle. It consists of a fixed block which is rigidly fastened to the gage head case, and a

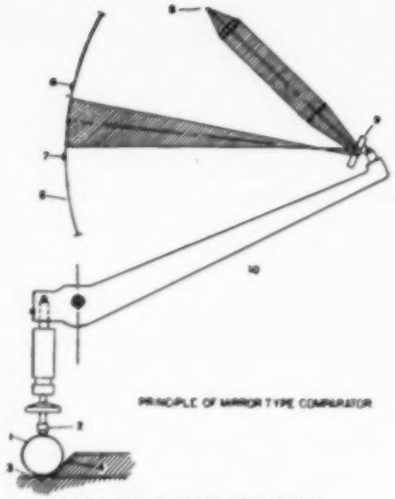

FIGURE 4—MIRROR TYPE COMPARATOR

floating block which carries the gaging spindle and is connected horizontally to the fixed block by reeds. A vertical reed is attached to each block, with the upper ends fastened together and fixed to the pointer. A linear motion of the spindle moves the free block vertically, causing the vertical reed on the floating block to slide past the vertical reed on the fixed block. Since the two reeds are fastened together, the movement of the spindle actually causes the reed to arc in a movement greater than the spindle motion. In the optical type, magnification is obtained through the use of the light beam which projects the shadow of the pointer on to the calibrated scale by means of a lens and prism circuit. The movement of the pointer shadow, projected on a scale, is proportional to the motion of the spindle. The lens system can be changed to suit the amplification desired in each comparator.

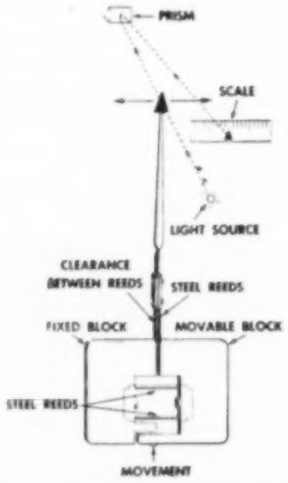

FIGURE 5—REED MECHANISM WITH OPTICAL PROJECTION

ELECTRIC COMPARATOR

Comparators employing the true electric circuit in the measurement or classification of work pieces can be defined in two groups; one, the limit type, and two, the indicating type. In the limit method of electrical measurement, the reed principle of motion transmission which we have just discussed, is employed and incorporated with special, sensitive microswitches. The circuit is connected to special light attachments which can be constructed to operate a light if the work is within tolerance and operate warning lights, if oversize or undersize. The color of the light system indicates which condition exists in the parts being measured. This type of gage is accurate to within

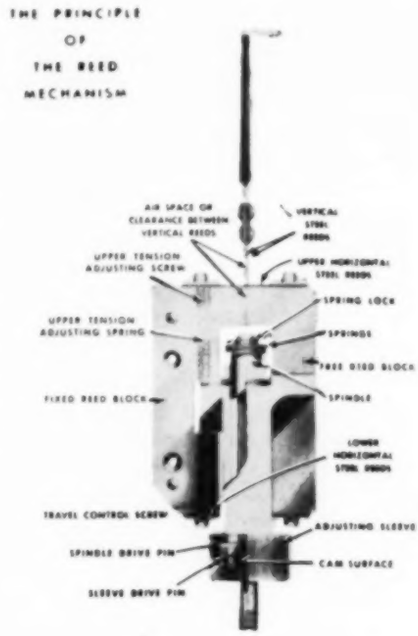

FIGURE 6—SCHEMATIC DIAGRAM OF REED PRINCIPLE

five millionths and has a tolerance range up to twelve thousandths. It is set through the use of gage blocks and is very rapid. The reed mechanism of the gage is equipped with a needle which swings as the target swings on a visual gage. The swinging needle breaks an electrical contact at each end of its swing. One terminal contact controls a red light, the other a green light. These terminals have micrometer adjusting screws for adjustment to the given tolerance, as shown in Figure 7. The reed-electric contact method of gaging can be applied directly on machine tool equipment by having the circuit operate the shutoff on the machine when defective material is being produced. In recent years, this electric principle has been em-

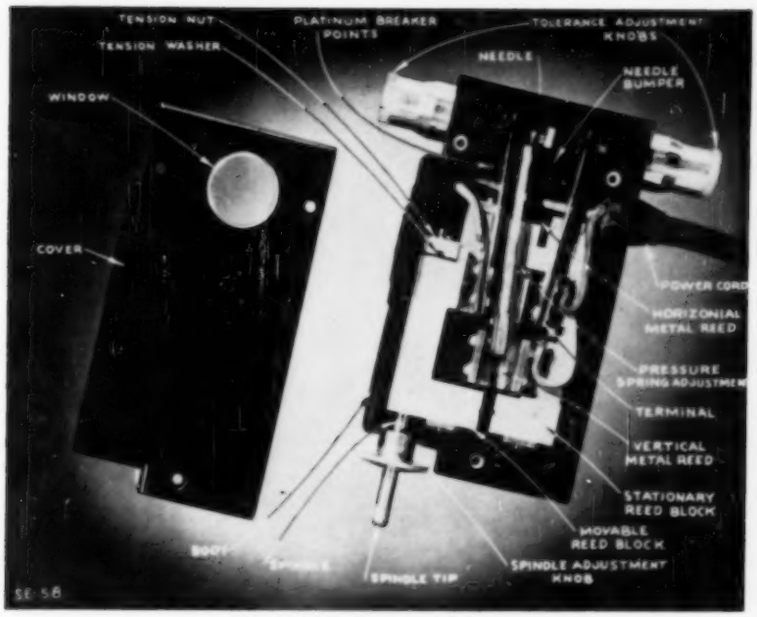

FIGURE 7—THE REED PRINCIPLE, ELECTRIC COMPARATOR (ELECTRICHECK)

ployed on multiple dimension gages used in mass production inspection of shells, cartridge cases, etc. It is a simple procedure to incorporate individual circuits to one master light which will flash on if all dimensions are within tolerance. When any one particular dimension is out of the tolerance range, the acceptable light will flash off and the single reject dimension light, indicating the particular error, will flash on.

ELECTRIC BRIDGE TYPE COMPARATOR

Another type of electrical comparator is based upon the effect of current flowing through an unbalanced electric circuit. This is an indicating method of electric measurement and shows actual deviations from basic size established by reference masters. The gaging head is an electrical unit and is connected to a micro-ammeter. As shown in Figure 8, the gaging head spindle bears against an armature, which is hinged at one end, the other being free to move between two coils of a balanced circuit known as a bridge circuit. When the spindle pushes against the armature it moves the armature away from one coil and closer to the other. This causes an electric current to flow, the amount of which is proportional to the motion of the spindle. This current is measured by the micro-ammeter which is calibrated in linear measurement rather than in micro-amperes. In some instances, particularly on multiple gages, the circuit can operate light signals instead of indicating actual measurements. A power unit is necessary. This consists of a voltage regulator to keep the supply voltage constant and a step-down transformer to reduce the voltage from 110 to 11. The current, which flows when the spindle moves, passes through a rectifier. This rectifier changes the current from Alternating to Direct so that it can be measured by the micro-ammeter. Magnification is achieved because a small movement of the spindle and the armature causes a definite amount of current to flow through the meter. The ratio between the micro-ammeter pointer movement and the spindle movement is the magnification factor of the comparator. This type of comparator, shown in Figures 9 and 10, has been found to be highly accurate because of the sensitivity which is achieved through the micro-ammeter circuit. Magnifications of one thousand to ten thousand times are optional in standard equipment of this nature. The indicating meter is not necessarily confined to the spindle assembly. This permits portable use of the gage by the design of portable internal measuring plugs for large diameters, and portable snap-type units for the O.D. measurement of heavy parts. The electrolimit gage has been applied on multiple dimension gages, as well as for automatic control of machine tool equipment. Adjustment in setting up the gage may be made by adjusting the air gap between the coils and the armature. The closer the coils are to the armature, the greater the magnification.

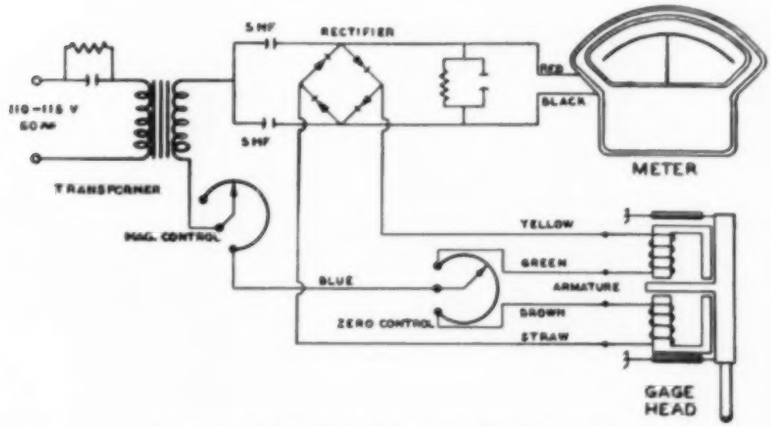

FIGURE 8—ELECTRO LIMIT SCHEMATIC DIAGRAM

ELECTRIC GAGE SYSTEM WITH ELECTRONIC AMPLIFICATION

The so-called electronic comparator is actually an electric system employing the use of an electronic principle for amplification. In the gage head itself are two fixed coils and one movable coil. The movable coil is mounted on the gage spindle and moves with it. Fixed coils are energized by a low frequency oscillator and are so arranged that zero current is induced in the movable coil when it is electrically centered between them. As the movable coil moves away from this electrical center toward either one of the field coils, the current induced in it increases in direct proportion to the distance it has moved away from the electrical center. In this manner, distance values are transformed directly into electrical values. Current in the movable coil is fed to a voltage-dividing network, controlled by the range switch. The output of the voltage-dividing network is greatly magnified by a stabilized amplifier. The amplifier houses all of the electronic circuits and on its front panel are the controls used in setting up the gage. A typical instrument is shown in Figure 11.

The amplified radio-frequency current is rectified by a detector circuit which converts this current into pulsating direct current. This direct current flows through a milliameter and records the amount of current flowing through the detector circuit. This rectified current in the detector is proportional to the amplifier radio-frequency current, and the amplified radio-frequency current is a multiple of the current in the movable coil in the gage head. The current in the movable coils is proportional to the movement of the spindle, and the movement of the milliameter needle, therefore, is proportional to the movement of the spindle. Consequently, the milliameter can be calibrated in terms of spindle movement. Direct current from the detector is also used to provide voltage in proportion to the spindle movement, actuating the grids of the limit-light control tubes, or, when desired, controlling electronically-operated auxiliary equipment for sorting or indicating.

Magnification of the electronic comparator may be reset by switching to the lowest of the four magnifications and using reference masters whose size difference is sufficient to produce a full scale deflection of the indicator. Full scale meter reading may be made to equal the size difference of the masters by adjusting the magnification control.

As in the case of the other electric circuits, the electronic plan has been applied successfully on multiple gaging applications, automatic sorting, and machine control.

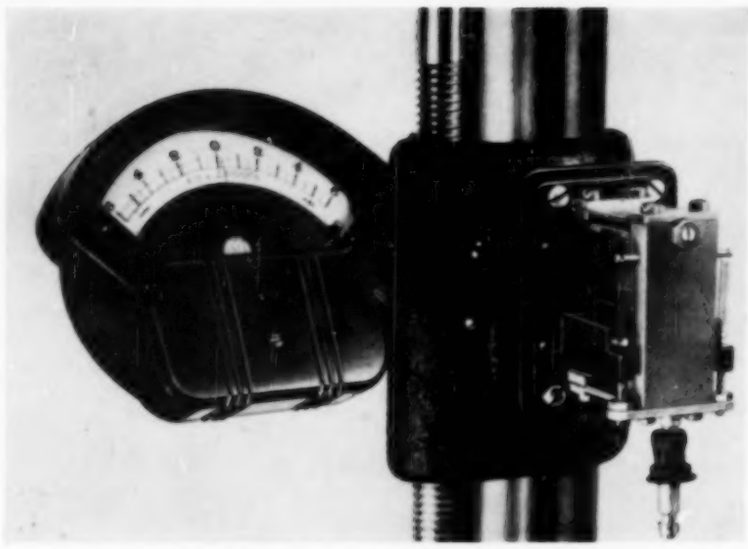

FIGURE 9—ELECTRO LIMIT GAGING HEAD

PNEUMATIC COMPARATORS

The pneumatic comparator, generally called an air gage, employs the air jet as a sensing means. This eliminates the necessity for the moving spindle which is the origin of measurement in most comparators. This unique fact permits the application of the pneumatic circuit on gaging problems where mechanical contact and mechanical motion must be kept at a minimum. When a surface approaches the nozzle, the discharge of air from the nozzle to the atmosphere is gradually reduced in a well defined relation to the clearance between the surface and the nozzle face. Visual indication of the nozzle clearance, and hence of the dimensions being measured, may be made with the use of a flowmeter in one type of system, or in other systems by means of the mono-meter or Bourdon tube pressure gauge. Generally, the air jet is located in a pneumatic plug for internal measurement or a pneumatic ring for external measurement. The air blows directly against the work being measured, although in some cases it may be used indirectly against a flapper or movable contacting point. A pneumatic gage system with a pressure actuated indicator is shown in Figure 12.

Compressed air is supplied to a pressure regulator through a filter, which removes the objectionable particles of foreign matter from the air stream. The regulator reduces line pressure to the pressure required by the instrument. A Bourdon tube type gauge is used as the dimension indicator. From the regulator the air passes successively through a restriction and through the gaging nozzles. As it passes through the restriction, the air undergoes a reduction in pressure, the amount of reduction depending on the rate of escape from the gaging nozzle. When the surface is away from the nozzle the rate of air escape is high. There is a large pressure drop through the restriction, and the pressure between the restriction and the nozzle is low. The dimension-indicating gage is actuated by this pressure. As the work surface approaches the nozzle, the pressure to the dimension-indicating gage increases with a very definite relation to the reduction

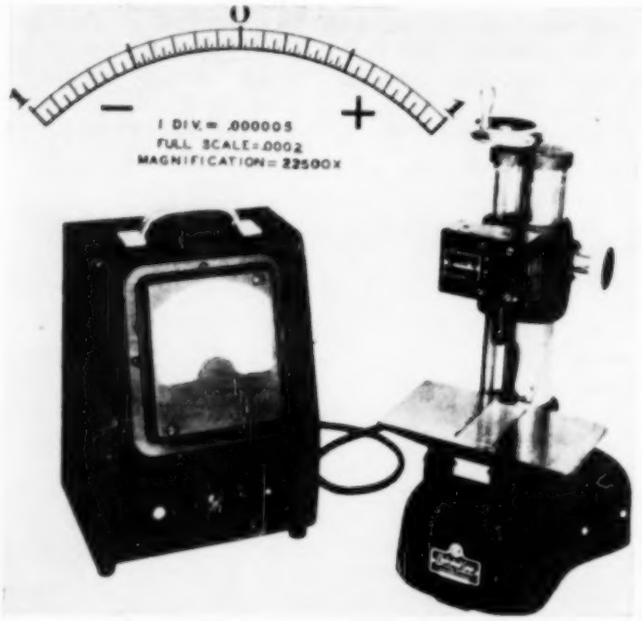

FIGURE 10—ELECTROLIMIT EXTERNAL COMPARATOR

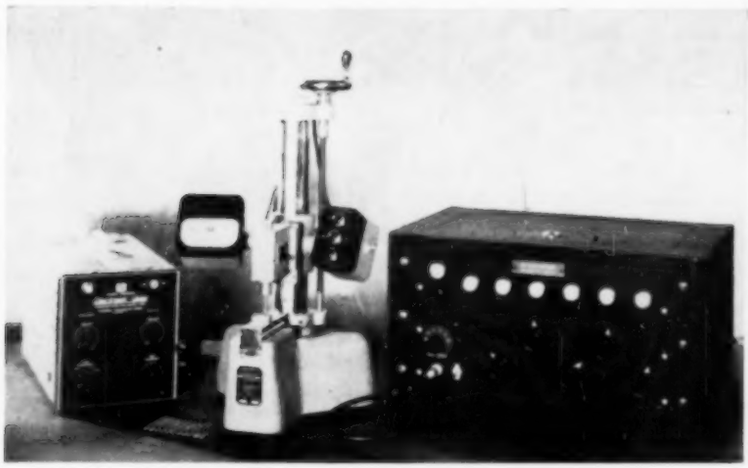

FIGURE 11—ELECTRONIC COMPARATOR

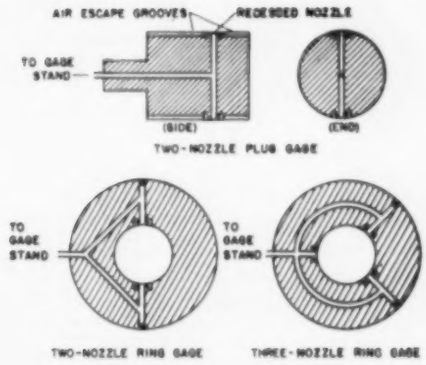

FIGURE 13—PNEUMATIC GAGING MEMBERS

in nozzle clearance. By controlling the size of the restriction and the original nozzle clearance built in the pneumatic member, it is possible to achieve amplifications as high as ten thousand times with standard pneumatic equipment.

There are two general classifications of air gages. One is the limit type which contains no true calibration, but is set by means of two reference masters. Work pieces are measured to within the tolerance limits so established. The other classification is the calibrated type, which in most cases is calibrated by means of two reference masters while the amplification is varied to match the graduations on the scale that suit the difference in size between the minimum and the maximum reference master.

The pneumatic comparator is particularly useful in exploring conditions of internal diameters. The pneumatic members used with the comparator are, in most cases, designed in such a manner that positioning of the work is not a factor during the gaging operation. It is the general practice to supply pneumatic members that contain two nozzles diametrically opposite. Side motion of the work piece on the pneumatic member is compensated by either one of the nozzles. This fact produces one of the advantages of this type of instrument in eliminating errors due to positioning of work pieces by the operator. The general design of pneumatic plugs and rings is shown in Figure 13. Also shown is a three-nozzle ring for detecting lobe conditions in centerless-ground shafts.

The wear life of the pneumatic members has also been an important reason for their general acceptance in the precision field, since, within limits, the wear on the outside diameter of pneumatic plug members, or on the inside diameter of O.D. measuring pneumatic members, does not affect the accuracy. The pneumatic comparator, like the electrical comparators already discussed, has been applied on multiple gaging operations. A gage for measuring, simultaneously, the I.D., the O.D., and the squareness of face to bore is shown in Figure 14. These gaging operations, single or multiple, can be indicated, or, through use of pressuretrol switches, made to operate light circuits. The pneumatic circuit has also been used in automatic machine controls and in automatic inspection equipment. One control circuit, for the inspection of continuous strip, is shown in Figure 15.

OPTICAL AND PROJECTION COMPARATORS

Projection comparators may be of the bench, floor, or pedestal-mounted types and are sometimes known as optical comparators, contour comparators, profile comparators, or shadowgraphs. The details and general appearance are shown in Figures 16 and 17. They differ from the optical projection systems we have previously discussed in the fact that they are complete comparators in themselves and the magnification is achieved solely by optical means. This fact restricts the

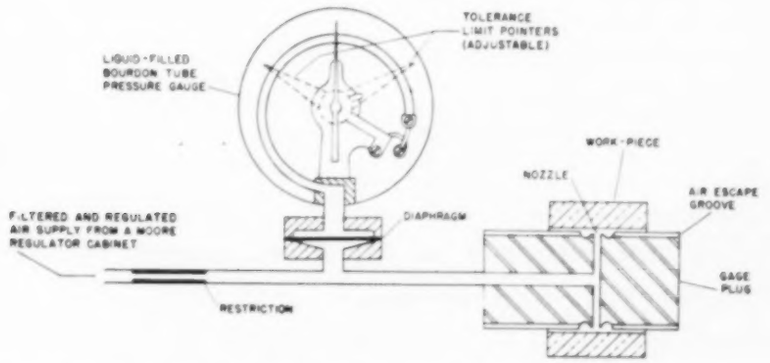

FIGURE 12—SCHEMATIC DIAGRAM OF SIMPLE PNEUMATIC COMPARATOR CIRCUIT

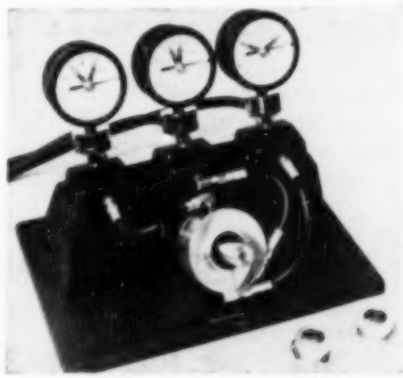

FIGURE 14—TRIPLE PNEUMATIC COMPARATOR

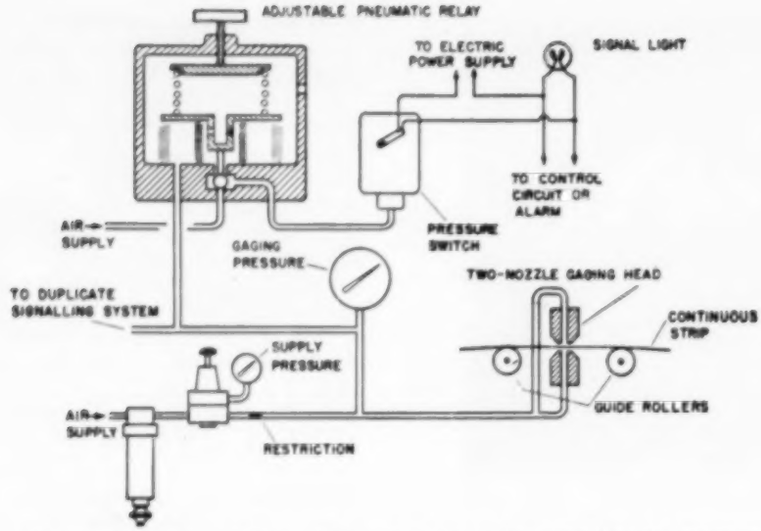

FIGURE 15—SCHEMATIC DIAGRAM OF PNEUMATIC CONTROL CIRCUIT

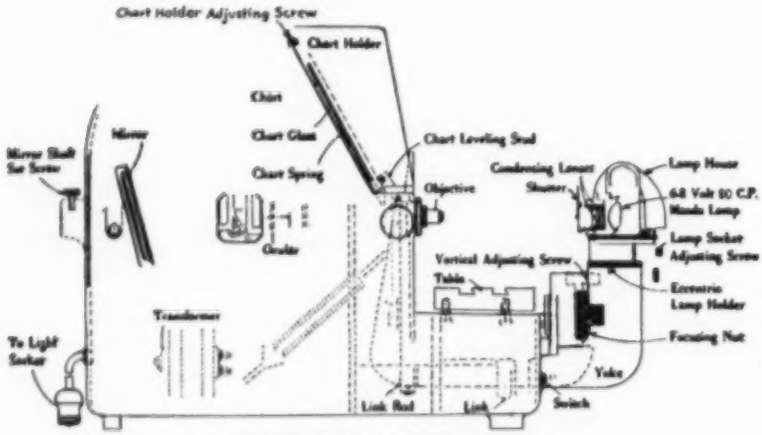

FIGURE 16—SCHEMATIC DIAGRAM OF OPTICAL COMPARATORS

amount of amplification to approximately four to one hundred times. The optical system consists essentially of a light source, condensing lenses, multiple focal lenses, multiple mirror, a glazed screen, and the supporting framework. The fundamental principle is similar to a lantern slide projector. The part to be checked is usually mounted on the table or in a fixture in such a way that a light beam can be directed across its surface to cast an enlarged shadow of its contour on a screen. The screen may be charted or calibrated to a basic size or shape of the part with additional lines to indicate the maximum and minimum tolerances. With special fixtures for rigid mounting, production parts are being measured with this type of comparator. Threads and contours, including taper or radii, can be readily checked on the optical comparator. This method of comparison is not adaptable to large work, but small parts can be entirely measured

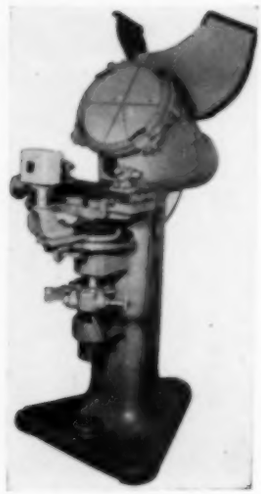

FIGURE 17—AN OPTICAL COMPARATOR

in one operation, in some cases, to tolerances as close as one ten thousandth.

SUMMARY

It is impossible to cover every type of modern measuring instrument offered to quality control methods today. The principles and applications discussed up to this point are those of the majority of standard instruments available. The development and application of these instruments, while relatively recent, has nevertheless been proved by numerous installations which are operating in the field.

With careful consideration of the self-evident advantages of each type of comparator discussed, it is possible for the quality control engineer to reach a conclusion on which system would be best suited for his individual requirements.

When in doubt, a good formula always to keep in mind is:—

1. The accuracy necessary.
2. The location and conditions under which the instrument will operate.
3. The type of personnel who will handle the instrument.
4. The type and quantity of work to be measured, with particular attention on the weight, type of material, cleanliness, etc.
5. The money available.

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Book Reviews

QUALITY CONTROL IN INDUSTRY: METHODS AND SYSTEMS

John G. Rutherford. Pitman Publishing Corporation, New York, 1948: 197 pages; $3.50. Review by Professor Irwin S. Hoffer, School of Business and Public Administration, Temple University.

"While the mechanics of the use of tools and the mathematics of statistical methods are well covered in available literature on quality control, and while the subject of general industrial organization has also been outlined very ably, little material has been written that contains both the general principles of quality control and the statistical techniques. The author feels that a combination of these associated subjects would fill a long-felt need of both the student and those in industrial work." This, in the author's preface, is the purpose for which the book has been written.

It is divided into two parts. The first part, on **General Principles,** covers the first third of the book, and is divided into eight chapters. The remaining two-thirds of the book, made up of six chapters, constitutes Part II, on **Statistical Methods.** An appendix that includes twelve tables, a glossary of symbols, and a list of statistical references concludes the work.

The first part of this book deals with two broad topics: the relation of the quality control function and department to the overall management of the firm; and the operation and control of the quality control department itself. The first of these topics is covered in Chapters 1-3 and 7-8. In the first three chapters the author considers the functions and responsibilities of the quality control department, its place in the general overall organization of company operations, and the economics of quality control. These are important topics and the discussion of them will be welcomed by quality control directors. In Chapter 3 the general principle of balancing the cost of the quality control function against the savings obtained by improved quality is discussed and the difficulties that arise in securing this balance are recognized. Chapter 2 shows how the quality control department may be constructed externally in its relation to general plant organization, and internally, within the quality control department itself. Various plans of organization are well illustrated by appropriate organization charts. In the first chapter, on functions and responsibilities, one of the functions of quality control is stated as, "The art of screening and accepting the least desirable parts that will satisfy given standards." Although the author explains that this may seem like an argument for lowered quality, "it actually assures that a company is not penalized by the rejection of parts that are functionally acceptable." This statement of function, in the judgment of the reviewer, is rather awkward and may produce confusion in the mind of a beginning student. It emphasizes the producer's point of view and suggests that the producer's risk is more important than the consumer's risk. Moreover, the art of screening applies to all the product and not only to the part that is accepted.

Also, in the first chapter, the point is made that frequently parts that are outside of tolerance should be accepted. Although the exercise of judgment in this respect often enters into the function of the inspector, this point seems to have too much prominence in a discussion of the inspector's function. In most cases quality that falls outside of "specs" must be rejected absolutely. Furthermore, in the opinion of this interviewer, the discussion of the function of the quality control department could well have included more reference to the significance of modern quality control for the general improvement of product quality and acceptability.

In Chapter 7 the functional relation of the quality control department to other departments, such as manufacturing, engineering and sales is considered. Chapter 8 considers the relation of the quality control department to customer representatives. In the intervening chapters, 4-6, the internal control and operation of the quality control department is considered. The training of inspection personnel and the making of records and reports are included and practical suggestions made regarding procedures, forms and training programs. The inclusion of the topics of Part I in this text on quality control will be a helpful introduction to further study of these topics by both student and industrial worker.

The latter two-thirds of this book are devoted to a consideration of **Statistical Methods.** These methods, as presented, include a consideration of general principles, sampling inspection, process control, analysis and evaluation of data, and a final chapter on the practical application of statistical methods.

The discussion of general statistical principles is compressed into a mere twenty-one pages. The author attempts to introduce the student to random sampling, mathematical probability, the binominal, normal and Poisson distributions, and the estimation of population values from sample measures. It would be unfair to imply that a complete discussion of these topics is attempted by the author but the student of statistical methods will need to do extensive reading in statistical literature in order to secure an adequate understanding of these topics. A few inaccuracies may be noted. The fraction 1/6 has been rounded to .1666 in some places and to .1667 in others. A range of "17 to 49," page 78, is given as "18 to 49" elsewhere on the same page. In a general note on page 77, a minimum of 15 samples is required for the estimate of a population value; obviously small samples are meant, but the statement should include the qualification.

In Chapter 10 an introduction to the principles and methods of sampling inspection is offered. The distinction between Lot Quality Protection and Average Outgoing Lot Quality Protection is clearly explained. The determination of an economical sample size is illustrated, the discussion leading up to the use of the Dodge-Romig tables. An example of the use of these tables in a single sampling plan is given. Double and multiple sampling methods are mentioned but are not discussed. A slight inaccuracy occurs in Figure 47, page 99. The Cost of Sampling Inspection and Cost of Reinspection of Acceptable Lots does not add up at all points to Total Inspection Cost. The chapter, nevertheless, provides a lucid introduction to this particular phase of the quality control function.

The discussion of process control, in Chapter 11 seems least satisfactory of all the chapters in the text. A definition of process control is followed by the statistical theory of process control. Considerable space is given to the explanation of the multiplier which is applied to average range ($\bar{R}$) in order to obtain the

lot standard deviation. The implications of the analysis of variance are hinted at, but not explained. A practical application is presented in considerable detail. A single control chart for average and range is presented in connection with the practical example. It would seem that a more effective presentation would have started with the control chart based on the practical example. The statistical and logical theory underlying the chart, the preliminary analysis required, and subsequent procedures could then be presented. To this reviewer, at least, this would seem to be more effective pedagogically. A further criticism of this chapter may be made of the fact that no reference is made to the chart for percent defective or that for the number of defects. In Figure 50, page 108, the letters A, B, C, D in the diagram are either disarranged or omitted.

"Specialized Applications" are presented in Chapters 12 and 13. The construction of frequency series is discussed. Some attention is rightly given to the proper choice of cell limits. On page 141, line 9, the appropriate cell limits, however, are 237.5 to 252.5, 252.5 to 267.5, since the readings are taken to the nearest 10 lbs. It is unfortunate, from the student's standpoint, that an example was used in which the readings are taken in intervals greater than unity. Differences between means and standard deviations, for small and large samples, are discussed in Chapter 13. The several methods suggested in these two chapters should be used, as suggested by the author, in the analysis and evaluation of data provided by inspection and process control procedures. A final chapter summarizes in practical fashion the application of statistical methods in quality control procedures.

One final criticism may be offered in that the entire discussion in this book is based on the mechanical industry and the production and sampling of piece parts. Because of the increasingly widespread application of statistical quality control to other forms of manufacturing more attention in the general methodological literature should be given to the production of chemicals, the bulk industries such as milling, and the continuous product industries like the paper industry and the production of many textile products.

Two commendable features of this text should be noted. Each chapter closes with a concise summary, which will prove helpful to all students. Besides, the discussions are well supported by seventy diagrams, charts and figures which greatly enhance the presentation.

On the whole, this book should prove helpful to "both the students and those in industrial work."

Review by F. E. Satterthwaite, General Electric Company, Bridgeport, Connecticut

The purpose of this book is to combine under one cover the organization and the operation of an Inspection Department together with an outline of statistical techniques that are useful in accomplishing the inspection job. Thus, Part 1 contains generalized information outlining healthy organizational practices and methods and Part 2 explains and illustrates statistical procedures that may be economically applied by a well-functioning quality department.

Part 1 is a very good outline of the work which an Inspection Department must do. It particularly gives advice on questions which must be decided by management in order that an Inspection Department can operate efficiently and effectively. The first chapter covers functions and responsibilities. The distinction is made between the old line inspection function of screening out unsatisfactory parts and the fairly recent addition of process control.

Chapter 2 goes into detail on the organization of a Quality Control Department. The various possible organization patterns are outlined and their advantages and disadvantages clearly stated.

Chapter 3 discusses the economics of Quality Control. Too many of the control organizations have not faced this problem realistically and it is refreshing to see an emphasis on this important point. This is continued in Chapter 4 with a discussion of the control of quality-department costs. This discussion includes an outline of methods of operation, manpower requirements and training, and budgetary control.

Chapter 5 covers the reports and records which have found a place in quality and inspection operation.

Chapter 6 discusses personnel training including training school and in-service training methods. The economic value of training courses is covered with a good discussion. Finally, Part 1 closes with Chapter 7 on relations with other departments and Chapter 8 on customer representatives.

Part 1 will be a great help to the typical Quality Control Engineer who is usually brought on to the job with little or no practical experience in the inspection field. The Quality Control Engineer will find here a complete check list of the problems he will have to consider and suggestions as to how he should meet them. One of the major limiting factors in extending applications of Quality Control is the unbalanced know-how among Quality Control Engineers, skilled in use of techniques but unskilled in methods of getting them accepted. Needless to say, experienced inspectors will also enjoy reading Part 1 for the new viewpoint which it gives them.

Part 2 deals with statistical methods. This part is written at a more or less elementary level and can be followed easily by anyone with the equivalent of engineering training. The strong point of the presentation is the continual emphasis on looking at the problem as a whole and considering all factors that may affect the solution. Statistical methods are a tool to fill in the gap where other methods and available information are insufficient to get the answers. They do not replace common sense, good judgment and accumulated experience; they supplement and add to these qualities. Chapter 9 covers the principles of statistical methods with discussions of dice problems, the binominal distribution, the normal curve of error, and the Poisson distribution. Emphasis is placed on the use of the standard deviation to determine the variability of the statistics used.

Chapter 10 on sampling inspection is a clear description of lot quality protection plans (lot tolerance plan of Dodge and Romig). The example used in applying sampling inspection to aircraft steel bolts is very instructive. The intense study made of all factors which could affect the results practically assured that a good inspection plan would result. Statistics is shown as only one of the factors and is put in its proper place. The inexperienced reader may be a little curious as to why we can use a one percent sampling table and have a rough assurance of a lot quality of 0.1 percent defective after sampling inspection. We all know from experience that this is so, but it may be a little dangerous to put that kind of statement in a text book without backing it up with some kind of reasoning.

Chapter 11 on process control is also written with the viewpoint of a practical man. It might be mentioned that excellent diagrams are scattered throughout the technical presentation to make the point vivid and clear. The development of average and range charts is worked out in detail. Their use is emphasized through the complete discussion of the

Quality Control of spot welding. This example is very interesting in itself because of the wide use of welding processes and the difficulty of controlling them.

Part 2 closes with various specialized applications such as the treatment of raw data and frequency distribution analysis. Further discussion is given on small samples including the "t" test and the "F" test. The last chapter summarizes the practical application of statistical methods and outlines some of the pitfalls in their use and installation and some of the places where they are most likely to be accepted.

AMERICAN SOCIETY NEWS

MIDWEST SECTIONS MAKE SUSTAINING CONTRIBUTION

The Society acknowledges with much appreciation a gift of $500 from the nine Midwest Sections as a Sustaining Contribution to the American Society. This contribution is made from the proceeds of the Third Midwest Quality Control Conference, as were similar contributions following the first two Midwest Conferences.

This third contribution brings the total of such gifts from the Midwest Sections to $2000 and further strengthens the financial structure of the Society. The President has conveyed to each Midwest Section and to Mr. James M. Ballowe, General Chairman of the Third Midwest Conference, the Society's appreciation for this support.

EXECUTIVE COMMITTEE MEETS

A very successful meeting of the Executive Committee was held on February 16 at Rochester, N. Y. All but two of the twelve members of the Executive Committee were present or were represented by alternates.

The Executive Secretary reported that the membership of the Society on February 9, 1949, was 2308, of whom 67 were Fellows, 1001 were Senior Members, and 1240 were Members. This present membership of 2308 is a considerable expansion from the membership of 2101 at June 30, 1948.

The Treasurer reported that receipts between July 1, 1948 and February 1, 1949 had been $15,423.28. During the same period, expenditures had been $11, 685.18. The balance on hand in the Society operating account was $10,765.-34 on February 1, 1949.

Mr. R. S. Saddoris, Chairman of the Advertising Committee presented the Executive Committee with detailed suggestions and recommendations for carrying out a more effective advertising program in INDUSTRIAL QUALITY CONTROL. This report brought out clearly the problems faced in securing and maintaining advertising contracts and gave suggested goals to which the Society should work in strengthening its position from an advertising point-of-view.

The Executive Committee received reports from the Shewhart Medal Committee and the Brumbaugh Award Committee regarding progress in the work of these Committees.

Very encouraging information was received concerning the plans and program for the Boston Convention on May 5 and 6, 1949.

The Executive Committee considered the matter of annual conventions in 1950 and subsequent years. A number of invitations had been received from many cities for these meetings. It was finally decided to hold the 1950 Convention in Milwaukee, the 1951 Convention in Cleveland, and the 1952 Convention in Syracuse.

The President reported the Sustaining Contribution from the Midwest Sections which has been noted above.

Plans were made for preparation of the Society Yearbook for 1948-49. It was decided to issue the Yearbook with a complete list of members and their Section affiliations but without complete addresses. The Yearbook is expected to be available prior to the Annual Convention in May.

Numerous other matters were given detailed consideration during the meeting, and action taken in connection with a number of them is recorded elsewhere in this issue of the magazine.

WORK OF THE SHEWHART MEDAL COMMITTEE

The Shewhart Medal Committee has presented the Society with a comprehensive report of its activities during the past year. This record of committee work is outstanding and has been acclaimed by the Executive Committee of the Society.

Members of the Shewhart Medal Committee are: Philip L. Alger of Schenectady, N. Y. (Chairman); Mr. Charles A. Bicking of Wilmington, Del.; Mr. Ernest L. Fay of Moline, Ill.; Mr. G. Rupert Gause of New York, N. Y.; Mr. Irwin S. Hoffer of Philadelphia, Pa.; and Mr. Andrew I. Peterson of Monroe, N. Y.

The Shewhart Medal Committee raised a fund totaling $1,801.50 which has been turned over to the Treasurer of the Society to create the Shewhart Medal Fund.

The Committee engaged the artist, Robert Weinman, to execute the medal, and the Medallic Art Company to make the dies and prepare the medals with suitable engraving each year.

Of the present Shewhart Medal Fund, approximately $1,600 is obligated to the Medallic Art Company for its work on the medal, thus leaving roughly $200 for the medals of future years.

The Committee reported its selection of the Shewhart Medalist for 1948.

SHEWART MEDALIST FOR 1948 CHOSEN

The Shewhart Medal Committee has announced its selection of Colonel Leslie E. Simon of Aberdeen Proving Ground, Maryland, as Shewhart Medalist of the Society for 1948. Colonel Simon thus becomes the first medalist of the Society and the first member to receive the Shewhart Medal.

Colonel Simon is a Fellow of the Society; he is Director of the Ballistics Research Laboratory at Aberdeen Proving Ground.

The Medal will be presented to Colonel Simon at the Annual Convention Dinner in Boston on May 5, 1949.

RECOMMENDED FUTURE PROCEDURE OF THE SHEWHART MEDAL COMMITTEE

The Shewhart Medal Committee has made the following suggestions regarding the future work of this Society Committee, and these suggestions have been approved by the Executive Committee:

1. The committee will consist of 9 members, with 3 appointed each year for a three year term. The chairman will hold office for only one year, the new chairman being selected by the President from one of the 6 hold-over committee members.

2. The committee will have full power to select the medalist, prepare the citation, and arrange the presentation ceremonies. However, the decisions of the committee will be subject to review by the Executive Committee of the Society.

3. Not later than 6 months prior to the date of the annual convention of the Society, the Chairman of the Shewhart Medal Committee will write a letter to each National Director of the Society, inviting them—in consultation with Section officers—to submit suggestions for the medalist to the committee. In making suggestions each National Director should consider all eligible persons, and not merely those who are members of his own section.

Also, at the same time, the chairman of the medal committee will invite each committee member to make formal nominations for the medalist.

Any member of the Society who desires to suggest a nominee may make his proposal to a member of the committee or to a National Director.

4. Any person who, in the opinion of the committee, is noted for outstanding leadership in the field of modern quality control will be eligible for the award. This accords with the inscription on the medal itself. Persons who are not members of the Society, both at home and abroad, are eligible but preference will be given to Society members.

5. The committee will set a closing date for nominations, to be not less than 3 months before the annual convention, and will meet to make its final selection immediately after this date. The committee will prepare a suitable citation, describing the accomplishments for which the award is made.

6. As soon as the concurrence of the Executive Committee has been obtained, the chairman of the medal committee will notify the medalist of his selection. As soon as the medalist's acceptance is received, announcement of the award will be made to the press and in the journal of the Society.

7. The presentation of the medal will be made at a general meeting of the Society during the annual convention each year.

BOARD AND COMMITTEE MEETINGS DURING BOSTON CONVENTION

Many Board and Committee members, who would not find it possible to undertake travel for the sole purpose of attending Board or Committee meetings, will be present for the Convention in Boston. It will therefore be highly desirable for the Board and Committee chairmen to take every possible advantage of this circumstance and to plan such meetings in Boston at that time.

In addition, the National Officers plan to meet during the Convention with all Section Officers present to discuss matters regarding Society administration. This meeting will be a continuation of the meetings held in Chicago last November.

A schedule of meeting times is being prepared and each committee will be assigned time and rooms for its meetings at the Convention. Board and Committee chairmen will provide the members of their several groups with information concerning the meetings as soon as it becomes available.

NEW COMMITTEE CHAIRMAN

Mr. Clifford W. Kennedy of Federal Products Corporation, Providence, R. I., has accepted appointment as Chairman of the Committee on Publicity and Public Relations. This appointment received unanimous approval of the Executive Committee at its meeting in Rochester.

Mr. Kennedy has wide contacts with quality control men throughout the United States and Canada and is preparing plans for developing the Society's program of public relations work in industry.

SOUTH TEXAS SECTION RECOGNIZED

At its meeting in Rochester on February 16, the Executive Committee unanimously approved the application of the South Texas quality control group for recognition as the South Texas Section, ASQC. Thirteen memberships have been received by the Executive Secretary for the new Section. Officers elected by the Section are:

Chairman.....A. R. Burgess
Vice Chairman.....C. H. Bone
Secretary-Treasurer.....B. L. Cloud

Headquarters of the South Texas Section will be in Houston; it will be part of the Midwest Region of the Society, of which Mr. Arthur Bender, Jr. is Regional Director.

The Society welcomes the organization of this Section in the industrial area of Texas.

NOMINATING COMMITTEE REPORT

The Nominating Committee of the Society has reported its nominations for national officers in the Society year 1949-1950 are as follows:

President:
Ralph E. Wareham
Vice-President:
Wade R. Weaver
Executive Secretary:
Simon Collier
Treasurer:
Alfred L. Davis

Members of the Nominating Committee are: Elwood E. Folsom (Chairman), George D. Edwards, Ralph A. Hefner, Wyatt H. Lewis, Paul S. Olmstead, Ernest H. Robinson, and Herbert G. Winter.

BY-LAW FOR MEMBERS-IN-TRAINING

The Executive Committee has approved a By-law covering Members-In-Training and Student Branches. The by-law was drafted by Mr. George D. Edwards from the recommendations of the Committee on Constitution and By-laws.

This by-law outlines the basis for enrollment as a Member-In-Training and attendant privileges; it specifies the manner in which Student Branches may be organized.

The by-law will now be submitted to the Board of Directors for approval.

SUMMER SESSION IN STATISTICS

The Institute of Statistics of the University of North Carolina announces a statistics summer session, June 9 to July 19, 1949, at Chapel Hill, N. C. Advanced courses will be offered in probability, sequential analysis, and the design of experiments.

An announcement of this summer session may be secured by writing to Director, Institute of Statistics, University of North Carolina, Box 168, Chapel Hill, N. C.

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Simon Collier
Executive Secretary, ASQC
22 East 40th Street
New York 16, N. Y.

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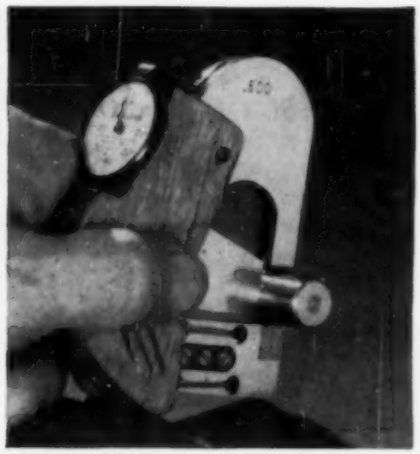

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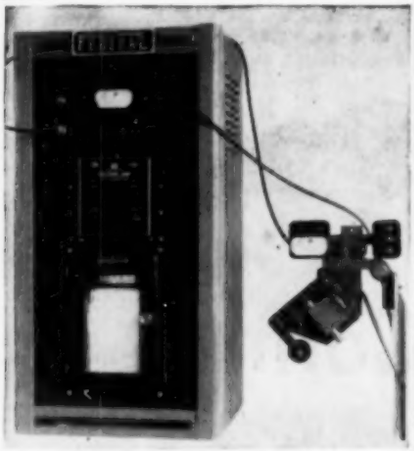

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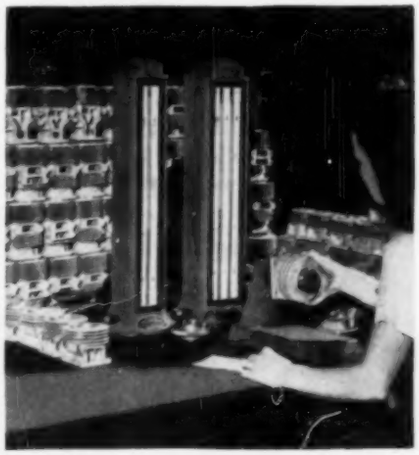

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